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The Engineer

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The *FASTEST* through-feed Centreless Grinders for bars, shafts and tubes

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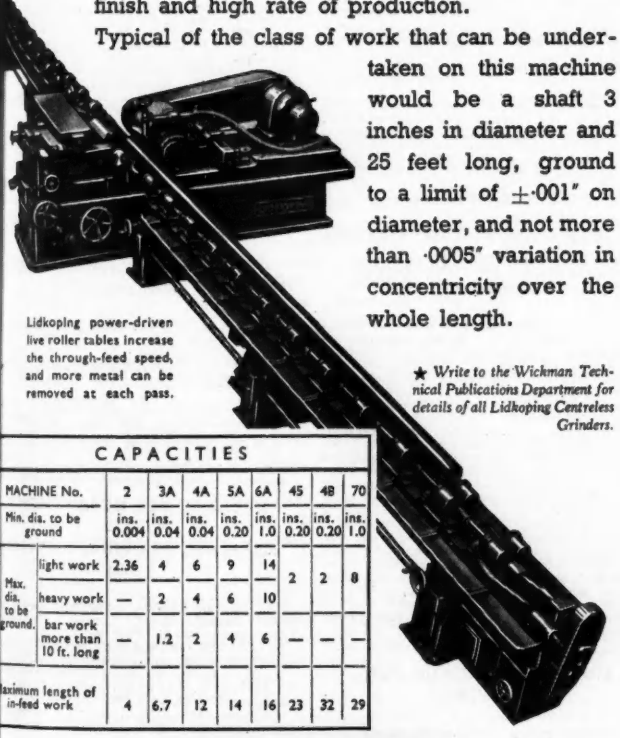

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★ *Write to the Wickman Technical Publications Department for details of all Lidkoping Centreless Grinders.*

CAPACITIES

MACHINE No.		2	3A	4A	5A	6A	4S	4B	7O
Min. dia. to be ground		ins. 0.004	ins. 0.04	ins. 0.04	ins. 0.20	ins. 1.0	ins. 0.20	ins. 0.20	ins. 1.0
Max. dia. to be ground.	light work	2.36	4	6	9	14	2	2	8
	heavy work	—	2	4	6	10			
	bar work more than 10 ft. long	—	1.2	2	4	6	—	—	—
Maximum length of in-feed work		4	6.7	12	14	16	23	32	29

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THE ENGINEER

ESTABLISHED 1856

Vol. 195 No. 5065

FEBRUARY 20, 1953

28 Essex Street, Strand, London, W.C.2

Telephone : CENtral 6565 Telegrams : Engineer Newspaper, Estrand, London

Published every Friday Registered as a Newspaper

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NOTICE TO READERS

All letters intended for insertion in 'The Engineer' or containing questions should be accompanied by the name and address of the writer, not necessarily for publication, but as a proof of good faith. No notice whatever can be taken of anonymous communications. No undertaking can be given to return drawings or manuscripts; correspondents are therefore requested to keep copies.

SUBSCRIPTIONS

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Advertisements received by Mid-day Tuesday will appear in the issue of Friday the same week. Orders must be accompanied by a remittance.

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PUBLIC APPOINTMENTS

THE UNIVERSITY OF MANCHESTER

ASSISTANT LECTURER IN ENGINEERING

Applications are invited for the post of ASSISTANT LECTURER IN ENGINEERING. Candidates should have qualifications in civil engineering, with special interests in structures or hydraulics. Salary not less than £450 per annum, with membership of F.S.S.U. and children's allowance scheme.—Applications should be sent not later than 11th March, 1953, to the Registrar, The University, Manchester, 13, from whom further particulars and forms of application may be obtained. E7392

MINISTRY OF EDUCATION

H.M. INSPECTORS (MEN AND WOMEN)

Ministry of Education requires H.M. INSPECTORS (Men and Women), preferably under 50. Appropriate professional qualifications and teaching and practical experience desirable in agriculture, mechanical engineering, mining, architecture, building or management studies.

Posts permanent and pensionable. Inclusive salary : London £1075 by 12 increments to £1625 (men), £970 by 11 increments to £1438 (women). Elsewhere slightly less. A few posts carry £100 allowance. Appointments may exceptionally be made above the minimum. Higher posts filled by promotion.

Application form from the Secretary (Inspectors' Section), Ministry of Education, Curzon Street, London, W.1. Closing date 31st March. E7410

BRITISH ELECTRICITY AUTHORITY

DRAWING-OFFICE

SENIOR DRAUGHTSMEN

British Electricity Authority, Drawing-Office, Headquarters, Bankside, London, require SENIOR DRAUGHTSMEN (Grades 4 and 5), with experience in the layout of power stations or who have been employed in a power station drawing-office.

SENIOR DRAUGHTSMEN (Grade 5), with experience in R.C. design and detail for light structures and foundations required for main grid substations.

DRAUGHTSMEN (Grade 6), with experience in the preparation of electrical diagrams or graphs, charts and statistical work.

Senior draughtsmen should be at least 26 years of age. Starting salaries will be in accordance with qualifications and experience : N.J.B., Grade 4, £705–£819 ; Grade 5, £595–£705 ; Grade 6, £458–£595. Pension scheme. One Saturday in four on duty.—Forms from D. Moffat, Director of Establishments, British Electricity House, Winsley Street, London, W.1. Quote reference E/323. E7376

THE BRITISH COTTON INDUSTRY RESEARCH ASSOCIATION (SHIRLEY INSTITUTE)

HEAD OF SPINNING DEPARTMENT

Physicists, Research Engineers and Textile Scientists are invited to apply for the position of HEAD of the SPINNING DEPARTMENT at the Shirley Institute. The Department, which at present has a staff of about sixty, engages in research into the processes and products of the cotton spinning industry, and into the development of new machines. It deals with cotton, silk, rayon and synthetic fibres and provides technical services to the various industries that use cotton spinning machinery. The Head is required to superintend all the activities of the Department, to help with the presentation of results to the scientific world and to the industry, and to help in the formulation of research and development policy. There is an extensive programme of long-term research, and it is important that the Head should be able to influence considerably the progress of this work. The Department is adequately staffed with people having knowledge of the industry and its technology and knowledge of textiles is not essential. Candidates will therefore be considered primarily for their qualities of leadership, initiative and judgment, and for their qualifications and experience as research scientists. A salary of up to £2000 per annum will be paid, with participation in the Federated Superannuation System for Universities.—Applications should be made to Dr. Toy, Director of Research, Shirley Institute, Didsbury, Manchester, 20. E7437

MINISTRY OF SUPPLY

ELECTRICAL OR MECHANICAL ENGINEER AS SCIENTIFIC OFFICER

Ministry of Supply, R.A.E., Farnborough, Hants, requires ELECTRICAL or MECHANICAL ENGINEER as SCIENTIFIC OFFICER, for research and development in connection with generation, conversion and control of electric power for aircraft. Work includes planning of general layout of aircraft supply system, design and development of rotating machinery and associated control equipment to meet special conditions of operation encountered in modern aircraft and guided missiles, and allows considerable scope for originality in devising associated equipment. Quals.: First or Second-Class Hons. Degree or equiv. in Engineering or in Physics or Mathematics, with subsequent elec. eng. experience. Experience of original work in design of dynamo electrical machinery may be advantage. Salary within range £417–£675 ; women somewhat less. Post unestablished. F.S.S.U. benefits may be available.—Application forms from M.O.L.N.S., Technical and Scientific Register (K), 26, King Street, London, S.W.1, quoting D 54/53A. Closing date 14th March, 1953. E7447

COUNTY COUNCIL OF ESSEX

COUNTY ARCHITECT'S DEPARTMENT

SENIOR ASSISTANT HEATING ENGINEERS

Applications invited for appointment on the established staff of :

SENIOR ASSISTANT HEATING ENGINEER, Grade VII, A.P.T.D. Salary at a rate not exceeding £785.

SENIOR ASSISTANT HEATING ENGINEER, Grade VI, A.P.T.D. Salary at a rate not exceeding £735.

Candidates should be Associated Members of the Institution of Heating and Ventilating Engineers, and must be fully experienced and competent to design and prepare detailed plans, specifications, schedules and estimates of cost of modern mechanical engineering plants, including heating and hot water services.

In fixing the commencing salary in each case regard will be had to the experience and qualifications of the successful candidate.

Application forms obtainable from County Architect, H. Conolly, F.R.I.B.A., County Hall, Chelmsford, Essex (please state post for which form is required), to whom they should be returned accompanied by copies of not more than three recent testimonials by Monday, March 2nd, 1953.

Canvassing disqualifies. E7391

HER MAJESTY'S COLONIAL SERVICE

PUBLIC WORKS DEPARTMENT

EXECUTIVE ENGINEER

Applications are invited for the following post :—

EXECUTIVE ENGINEER, Headquarters Road Laboratory, Public Works Department, Nigeria.

Candidates must hold a recognised University Degree or Diploma in Civil Engineering carrying exemption from Parts A and B of the A.M.I.C.E. examinations, and have studied Soil Mechanics up to B.Sc. level. They must have had experience in field and laboratory, a knowledge of site investigations for roads, aerodromes, building foundations, &c.; be capable of organising and controlling central and mobile laboratories, and of training staff ; be conversant with the following subjects :—Plasticity, index, grading, shear, C.B.R.; permeability and consolidation tests on soils and their application to design of roads, aerodromes, structural foundations, &c.; testing of soils, concretes and bituminous materials and taking of undisturbed samples from pits and boreholes. Appointment is on contract/gratuity terms with basic salary in scale £715 by £44 to £1419 p.a., plus expatriation pay varying according to salary from £180–£300 p.a. Gratuity of £25 for each completed period of three months' service, or at the rate of £37 10s. where basic salary plus expatriation is £1000 p.a. or over, also payable on satisfactory completion of contract.

Full details on application.

Apply in writing to the Director of Recruitment, Colonial Office, Great Smith Street, London, S.W.1, giving briefly age, qualifications and experience. Mention the reference number CDE 112/14/02. E7423

WELSH REGIONAL HOSPITAL BOARD

ASSISTANT QUANTITY SURVEYOR (ENGINEERING)

Applications are invited for the following post in the Engineer's Division :—

ASSISTANT QUANTITY SURVEYOR (Engineering). Salary £600 by £25 (7) by £30 (3) to £865.

The Board may fix the starting point above the minimum of the scale on the grounds of full professional experience and age.

Applicants must hold Corporate Membership of the Royal Institution of Chartered Surveyors and have experience in taking off and preparing bills of quantities from engineers' drawings (electrical, heating, &c.), pricing materials and work, checking tenders, contractors' accounts, &c.

The appointment is superannuable and is terminable by one month's notice on either side.

Applications, stating age, experience, qualifications and present position, together with the names and addresses of two referees, should be addressed to the Secretary, Welsh Regional Hospital Board, Temple of Peace and Health, Cardiff, so as to reach him not later than 10 days from the appearance of this advertisement. E7438

BRITISH ELECTRICITY AUTHORITY

YORKSHIRE DIVISION

MAINTENANCE ENGINEER (MECHANICAL)

British Electricity Authority, Yorkshire Division, require a MAINTENANCE ENGINEER (Mechanical) at Sculcoates Power Station, Hull.

Salary £787 to £818 per annum, N.J.B. Agreement, Class G, Grade 6.

Applicants must have had a sound technical training and experience in the operation of a modern power station, and preference will be given to candidates who are Corporate or Graduate Members of the Institution of Mechanical Engineers, or who hold equivalent qualifications.

Applications, on Form AE6, obtainable from Divisional Secretary (Establishments), British Electricity Authority, Yorkshire Division, British Electricity House, St. Mary's Road, Leeds, 7, to be returned within 14 days of the appearance of this advertisement.

G. A. VOWLES,
Divisional Controller.
E7420

SUTTON-IN-ASHFIELD URBAN DISTRICT COUNCIL

CONTRACT NO. 5

APPOINTMENT OF RESIDENT ENGINEER

Applications are invited for the above appointment, to supervise the construction of cast iron pipe sewers and sewage disposal works and pumping station constructed in reinforced concrete at Skegby. The work will be executed by contract and will be under the direction of the Consulting Engineers, Messrs. J. D. and D. M. Watson, MM.I.C.E., 18, Queen Anne's Gate, Westminster, S.W.1. The salary is £850 per annum, which includes £150 per annum to be considered as a lodging and subsistence allowance, which will not be subject to P.A.Y.E. deduction at source. The appointment, subject to satisfactory service, will last approximately two years and will be terminable by two months' notice in writing on either side.

Applicants, who should have had experience of similar work, should apply in writing to the undersigned, not later than 13th March, 1953, giving full particulars of age, qualifications and experience, and enclose copies of not less than two recent testimonials.

A car will be provided or, alternatively, if the applicant uses his own car, mileage allowance would be paid, together with reasonable expenses.

A statement should be made by the applicant that he is not related to any member of the Council or staff and has not canvassed anyone in connection with the appointment.

WALTER LAUGHTON,
Clerk of the Council.

Barclays Bank Chambers,
Low Street,
Sutton-in-Ashfield, Notts,
7th February, 1953. E7341

HER MAJESTY'S COLONIAL SERVICE

PUBLIC WORKS DEPARTMENT

CIVIL ENGINEERS

Applications are invited for the following posts :—

Vacancies exist for CIVIL ENGINEERS in the Public Works Department, Gold Coast. Duties include survey, design and construction of roads, bridges, buildings, water supplies, &c. Appointment is on probation for permanent and pensionable establishment in the Colonial Engineering Service, or on contract/gratuity terms in the Local Civil Service. Candidates, who should be under 45 years of age, must hold a recognised University Degree or Diploma in Civil Engineering carrying exemption from Parts A and B of the A.M.I.C.E. Examinations or be A.M.I.C.E. Candidates holding the qualification A.M.I.Mun.E. or possessing experience qualifying for Corporate Membership of the Institution of Water Engineers, can be considered for appointment on contract terms. Full details regarding salaries, allowances, conditions of service, &c., available on application.

Apply in writing to the Director of Recruitment, Colonial Office, Great Smith Street, London, S.W.1, giving briefly age, qualifications and experience. Mention the Reference Number CDE 112/13/04–05. E7399

AIR MINISTRY

R.A.F. AND CIVIL AVIATION STATIONS

MECHANICAL AND ELECTRICAL ENGINEERS

Air Ministry require MECHANICAL and ELECTRICAL ENGINEERS for design, operation and maintenance of ground mechanical and electrical works services on R.A.F. and Civil Aviation Stations, home and overseas. Appointments in Higher Grade, £970, rising annually to £1280 ; in Lower Grade, £628 at age 25 to £875 at age 34 (maximum starting salary), rising annually to £970. Provincial rates somewhat lower ; appointments non-pensionable. For overseas posts an annual allowance up to £1300 according to location. Only natural born British subjects. Minimum qualifications and experience: (i) (a) University Degree or equivalent in Electrical and/or Mechanical Engineering, with two years' apprenticeship, or (b) Graduate or Corporate Membership of the Institution of Electrical or Mechanical Engineers, with appreciable electrical engineering experience and three years' apprenticeship, and (ii) been in responsible employment for at least three years with well-established engineering concern. Application forms, quoting D.290/52/A, from M.L. and N.S., Technical and Scientific Register (K), Almack House, 26, King Street, London, S.W.1. E7411

HIGH COMMISSION FOR PAKISTAN

INSPECTORS AND ASSISTANT INSPECTORS

Applications are invited for posts of INSPECTORS (£600 by £20 to £680 p.a.) and ASSISTANT INSPECTORS (£500 by £20 to £580 p.a.) with headquarters in London.

Qualifications : Corporate Membership Institution of Mechanical Engineers or University Degree/Diploma carrying exemption from Parts A and B of Institution's exam., with either technical experience in manufacture, maintenance and/or inspection of railway wagons, locomotives, and other rolling stock, or experience and knowledge of diesel and steam power plants, road-making machinery and machine tools. Age 35/45 years.

Applications by letter, giving full details of qualifications and experience, to Establishment Officer, 35, Lowndes Square, London, S.W.1. E7457

ROYAL BUCKINGHAMSHIRE AND ASSOCIATED HOSPITALS MANAGEMENT COMMITTEE

ASSISTANT ENGINEER

Applications are invited from persons in possession of the Ordinary National Certificate for the post of ASSISTANT ENGINEER at Stoke Mandeville Hospital, Aylesbury, Bucks, a modern General Hospital of 624 beds. The successful applicant will be required to assist, under the direction of the Engineer-in-Charge, in the maintenance and operation of the engineering services of the hospital. Whitley Council conditions of service. Salary £425 by £15 to £500 p.a.—Applications, with three names for reference, to the Secretary, 9, Bicester Road, Aylesbury, by 2nd March, 1953. E7410

TENDERS

GRIMSBY, CLEETHORPES AND DISTRICT WATER BOARD

TRIAL BOREHOLES

The Board invite TENDERS from experienced contractors for the SINKING, PARTIAL LINING and subsequent TEST PUMPING of two 12in. diameter BOREHOLES :

Borehole A, situated in the parish of Stallingborough ; Borehole B, situated in the parish of Barnoldby-le-Beck, both sites being in the area of the Grimsby Rural District Council.

Specification and form of Tender may be obtained from the undersigned on or after 21st February, 1953, on payment of a deposit of Two Guineas, which will be refunded upon the receipt of a bona-fide Tender and the return of all documents.

The Board do not bind themselves to accept the lowest or any Tender.

W. R. BARNABY,
Clerk to the Board.

Town Hall Square,
Grimsby. E7454

COMMISSIONERS OF PUBLIC WORKS

SUPPLY OF MECHANICAL HANDLING EQUIPMENT

Sealed TENDERS addressed to the Secretary will be received up to, but not later than, 12 o'clock, noon, on the 12th March, 1953, for the SUPPLY and DELIVERY f.o.q., Dublin, of MECHANICAL HANDLING EQUIPMENT, consisting of Miscellaneous Steel Pallets and Accessories, in accordance with specification and conditions of contract, which may be obtained on application to this Office.

The commissioners will not be bound to accept the lowest or any Tender.

J. TYRRELL,
Secretary.

Office of Public Works,
Dublin,
11th February, 1953. E7455

INDIA STORE DEPARTMENT

TUBES, CUPRO NICKEL, FOR CONDENSERS

The Director General, India Store Department, 32/44, Edgware Road, London, W.2, invites TENDERS for the SUPPLY of :

TUBES, Cupro Nickel, for Condensers, ¾in. dia. by 18 B.W.G. thick by 13ft. length, qty. 11 approx.

Forms of Tender, which are returnable by Friday, 20th March, 1953, may be purchased from this office upon payment of a fee of 10s.

Reference D.O. 4746/52 must be quoted in applications. E7456

INDIA STORE DEPARTMENT

MACHINES, GRINDING, UNIVERSAL TOOL

The Director General, India Store Department, 32/44, Edgware Road, London, W.2, invites TENDERS for the SUPPLY of :

MACHINES, GRINDING, UNIVERSAL TOOL room 24in. by 5in., power feed, 400/440 A.C., qty.

Forms of Tender, which are returnable on Friday, 3rd April, 1953, may be purchased from this office upon payment of a fee of 10s.

Reference D.O. 4529/52 must be quoted in applications. E7457

INDIA STORE DEPARTMENT

GETTING READY MILL

The Director General, India Store Department, 32/44, Edgware Road, London, W.2, invites TENDERS for the SUPPLY OF :

One GETTING READY MILL, 18in. by 8in. Type : two high worm geared roll adjusting to non-reversing cold rolling mill.

Forms of Tender, which are returnable by Friday, 27th March, 1953, may be purchased from this office upon payment of a fee of 10s.

Reference D.O. 2998/52 must be quoted in applications. E7458

THE ENGINEER

FEBRUARY 20, 1953

Cocooning the "Princess" Flying Boats

THE second and third "Princess" flying boats are to be towed to the Calshot flying boat station, where they will be docked temporarily until the coupled "Proteus III" propeller turbine engines are available. As this period may be as long as two years, a method of preserving them in the manner of the Reserve Fleet has been adopted: it consists of cocooning them by a plastic spraying process. This process, which was initiated in America, has been further developed in this country by R. A. Brand and Co., Ltd., and the flying boat which last week was ready for launching represents the largest single unit ever to be hermetically sealed in this way. The total volume is approximately 40,000 cubic feet and the surface area involved amounts to 25,000 square feet. Before spraying commenced 18,000 lb of silica gel and quicklime desiccant were distributed in the structure. A typical spray gun consists of a number of nozzles, each emitting a single and extremely fine plastic fibre. Each continuous fibre, on solidifying, is entrained by an air jet and forms a serpentine thread of small pitch and increasing amplitude, according to the cone angle of the jet, until it settles upon the framework to be covered. The approximate weight of plastic sprayed in position was 9 tons. Three coats of plastic have been applied, giving a thickness of forty thousandths of an inch. Then a bitumen coat was applied to all surfaces and the area along the chine reinforced with a band of hessian to safeguard this area against abrasion during the towing of the machine. Another coat of bitumen of a different texture was then applied to the hull and all upper surfaces, giving an overall thickness of approximately one hundred thousandths of an inch. A final aluminium spray was then applied.

Atomic Propulsion for Ships

ON Tuesday of last week, Sir John D. Cockcroft read a paper with the title "Atomic Propulsion," with special reference to Marine Propulsion," before the Institute of Marine Engineers. He particularly mentioned the three submarine propulsion units using nuclear energy which are under construction in America, one of which was intended for the "Nautilus" and was designed to give an underwater speed of 20 knots. The nuclear reactor intended for the "Nautilus," he said, will be a "thermal reactor," in which metal-sheathed fuel rods of enriched uranium will dip into ordinary water, and the heat generated will be transferred by water under pressure to a steam generator. For the second submarine, "Sea Wolf," Sir John mentioned that an "intermediate reactor" was projected: in it the high-speed neutrons were not slowed down by water as in the "Nautilus" reactor, and this partial slowing down was of advantage since the materials surrounding the fuel absorb fewer neutrons at intermediate than at low speeds. The lecture was illustrated and slides showed the uranium nucleus splitting up, a cross section of the Harwell reactor which has a graphite core, and a smaller pile using heavy water instead of graphite. Another slide gave details of the neutron balance sheet when light uranium splits up and a graph showed the exponential rise in power level, which eventually steadies down. There was a diagrammatic arrangement of a propulsion unit in which heat was transferred to a steam generator by gas under pressure or liquid metal, which, Sir John explained, in addition to good heat transfer properties and low vapour pressure at high temperature, was more stable than water when subjected to intense radiation. The "fast reactor," which forms the basis for "breeding nuclear fuel," was described, and also a diffusion plant necessary for the production of enriched uranium. Turning to the question of economics, Sir John thought that, assuming a thermodynamic efficiency of 25 per cent, a plant developing 10,000 s.h.p. would require 12kg of fuel per year, or 60kg if the fuel had to be changed with only 20 per cent burnt up, but the initial cost of the nuclear plant would be three times that of the ordinary prime mover.

Fan Performance Test Code

A NEW fan performance test code based on current knowledge and practice has now been published by the Fan Manufacturers' Association. In presenting this code the Association points out that the first standard code for testing of fans —B.S. 848—was issued thirteen years ago, and although the new performance code retains much of the structure of B.S. 848, it is more precise and comprehensive in its presentation of test data and introduces new test methods in keeping with modern practice. The test methods adopted are suitable for fans having a pressure rise in excess of 28in w.g., and the code contains methods for correction for compressibility for use where the pressure rise exceeds 10in w.g. These corrections cover a range up to 200in w.g., and a chart is given for the correction of the efficiencies of high-pressure fans on an adiabatic basis. The definitions of terms relating to fans, pressures and instruments have been revised to bring them into line with present-day terminology, and a distinction is made between axial and propeller fans. To clarify the ambiguity in B.S. 848 under fan performance, a new term, "intake volume," has been introduced. The term "total head" has been dropped in favour of the more appropriate term "fan total pressure," and it is pointed out that the old association of fan pressure with water pressure is a relic that might well be discarded. In connection with the division of rectangular airways into areas for measurement purposes the new code gives two separate tables for the use of a pitot tube or anemometer. A comprehensive section deals with general instructions for performance tests, and a table of test methods required for different kinds of fans assists in the selection of the correct method. At a press conference presenting the new code, Mr. Geoffrey Woods said that the small number of manufacturers from the fan industry represented in the Association was to be deprecated in view of the useful work it was doing.

Reconstruction in the Coal Mining Industry

RECONSTRUCTION in the coal mining industry was reviewed by Mr. E. H. Browne, the National Coal Board's director-general of production, in an address delivered at Doncaster last Saturday to the Yorkshire branch of the National Association of Colliery Managers. Mr. Browne explained that, since vesting day, 124 major schemes, costing about £142,000,000, had been approved, but only £80,000,000 of that sum had been planned in sufficient detail for the actual expenditure to be authorised. Some gap between the two figures was to be expected and was indeed necessary, but Mr. Browne considered that the present gap was too wide. More significant still, he said, were the differences between the expenditure authorised and the work actually begun. Up-to-date figures were not available, but of £70,000,000 authorised for actual expenditure by last June, only £25,000,000 had been spent and only £15,000,000 worth of work was represented in uncompleted contracts or in jobs started but not finished. Thus, Mr. Browne added, there was £30,000,000 worth of work not begun or placed out to contract. He went on to say that only eleven major colliery projects had been completed, though many were overdue and the very large majority were seriously behind their programme. Five new shafts had been completed, Mr. Browne stated, nineteen were being sunk and three more had been approved but not yet started; thirty shafts had already been deepened and seventeen more were being deepened. Shaft sinking, Mr. Browne commented, and the provision of winding engines, were the cause of the longest delays in new schemes, and careful computation of cost had to be made especially where shafts were sunk through watered strata by the freezing or cementation methods. Whilst continuing to rely on really well constituted concrete, the Coal Board was watching with interest experiments with bitumastic and plastic linings.

Productivity Report on Plastics Moulding

THE report has now been published of the productivity team on plastics moulding, which visited the United States last year under the leadership of Mr. A. L. Sparshott. The team found that productivity was higher in the United States, and the report, like many previous reports, attributes this largely to the different attitude towards work of the American operative, better industrial relationships and incentives in the way of a greater availability of goods upon which to spend earnings. A number of recommendations are made in the report which, although it is pointed out is not applicable to all moulders in this country, should be studied by all with an open and receptive mind. It is considered that more specialists in engineering, design and liaison work should be trained, and there should be less emphasis upon greater physical effort by the worker and more upon positive improvement of methods. The lack of interchange of ideas and methods between British manufacturers is deprecated and greater co-operation at all levels is recommended. Various means for improvement of techniques in compression, transfer and injection moulding are suggested as a result of the studies made in American works.

International Mechanical Engineering Congress

AN announcement has been made this week about the fifth International Mechanical Engineering Congress which is to be held in Turin, Italy, from October 9th to 15th next. The congress, which will be taking place during the Salone Internazional della Tecnica, is being arranged by the Associazione Industriali Metallurgici Meccanici Affini of Italy, with the support of the organising committee. This committee consists of representatives of the mechanical engineering trade associations of Great Britain, Austria, Belgium, Denmark, Finland, France, Germany, Holland, Luxembourg, Norway, Spain, Sweden, and Switzerland. The theme selected for this year's congress is "Production and Assembly Methods for Components in Mechanical Engineering," the intention being to examine the subject both from the technical point of view and from the standpoint of production costs. The various methods available to industrialists for the design and manufacture of components will be considered. There will be fifteen working sessions of the congress, and it is stated that, in view of the wide scope of the general theme, it is not proposed to include consideration of raw materials, measurements, inspection, tests, or erection, but to concentrate rather on the technology of manufacture, methods of assembly, and comparative studies of different techniques. During the congress delegates will have an opportunity to visit certain industrial undertakings in and around Turin, and in the following week, October 16th to 22nd, there is to be a "study tour." Further particulars of the congress can be obtained in this country from the British Engineers' Association, 32, Victoria Street, London, S.W.1.

Water Power in the Italian Alps

No. II—(*Continued from page* 232, *February* 13*th*)

Following the introduction to Italian Alpine hydro-electric schemes which was given in last week's article, the series continues with a description of the Sarca River project. The principal power station of this scheme at Santa Massenza, an underground Pelton wheel installation, will be Italy's largest hydro-electric power station.

The Sarca River Project

THE Santa Massenza power station is a good example to take as an introduction to the modern underground power stations of northern Italy. The Societa Idroelettrica Sarca-Molveno was formed specifically for the purpose of constructing the Sarca river project, the Santa Massenza power station being one of the principal elements in this scheme. The company is owned by the Societa Edison (49 per cent), the Societa Idroelettrica Piemonte (49 per cent) and the Istituto Ricostruzione Industriale (2 per cent).

The accompanying diagrams, Figs. 5 and 6, show the layout of the entire project in plan and the relative elevations in the diagrammatic section, whilst production figures are shown in Table I. The parts of the scheme which are at present under construction are shown by full lines and the works which will have to be carried out in the future to complete the development of the catchment are shown dotted. The general position of the project may be noted from the position of Lake Garda to the south, into which the River Sarca flows. The headwaters of the Noce catchment will be diverted into the project in the later stages, as indicated in Fig. 5; the Noce is a tributary of the Adige, which is shown on the right of the illustration.

Seasonal storage will be provided at the principal reservoir of the scheme, Lake Molveno, to which a considerable volume of water will be diverted through the tunnels shown in Fig. 5, thus increasing by several times the flow available from its natural catchment. Lake Molveno is a natural lake formed by the rubble of an ancient landslide of considerable magnitude, which blocks its outlet to a depth of 125m giving a natural storage capacity of about 182 million cubic metres at the natural top water level of 825m above sea level. The construction of a dam at the outlet of the lake presents an unusual problem; as the reservoir level increases, so the seepage of water through the natural dam increases. Under natural conditions a balance has been maintained in which most of the flow out of the lake was underground. It was thought that damming above a level of 840m would be impracticable, due to increased seepage losses and also because of flooding of a highway and the hamlet of Molveno. Therefore, a dam is to be built in two stages, first 8m high, up to a level of 833m, to give a storage capacity of 207·5 million cubic metres, and secondly, a further 7m up to 840m above sea level, to give a storage capacity of 234 million cubic metres. Each of these stages is to be preceded by measures such as the construction of a water-tight diaphragm, to reduce seepage losses.

With extensive diversion aqueducts from the Sarca River, the total catchment diverted at the higher level into Molveno Lake (this section is referred to as Santa Massenza, No. 1) will be 520 square kilometres in extent, giving an average annual flow of 16·5 cumecs. The maximum draw down of the reservoir will be limited to a level of 740m above sea level during normal hydrological years, but for critical years an extra reserve is provided by this reservoir, which can then be drawn down to a level of 714m, the capacity between these levels being regarded as a year-to-year reserve. The second diversion system at the lower level leads into the Ponte Pia reservoir (Santa Massenza No. II), thus utilising a further 227 square cubic metres of catchment area with an average flow of 8·4 cumecs.

The tunnelling works involved in the diversion from Lake Molveno to the Santa Massenza power station were fairly straightforward, the excavation being mainly through limestone formations. The method of constructing the intake of Lake Molveno necessitated emptying the lake, and two shafts communicating with the completed diversion tunnel, and the floating pumping station shown in Fig. 7, were constructed for this purpose. The pumps were placed on the floating raft and discharged the waters of the lake into the tunnel, through various horizontal tunnels driven successively between

Table I—*The Sarca-Molveno Scheme*

Generating stations	Reservoirs	Useful storage	Average discharge	Average head	Installed power	Average yearly output		
						Winter 11/9–10/4	Summer	Total
		10^6 m³	m³/sec	m	kVA	10^6kWh/year		
Lago Scuro	Scuro Lake	1·500	0·051	809·0	2,000	2·6	—	2·6
Bedole	—	—	1·385	260·0	6,000	2·5	19·2	21·7
Genova	—	—	2·625	650·0	35,000	22·0	122·4	144·4
Cornisello	Vedretta Lake	2·400	0·114	444·0	1,800	2·4	0·9	3·3
	Cornisello Lake	15·720	1·090	768·0	26,000	31·5	20·4	51·9
Nambron	Gelato, Serodoli, Nero, Ritorto Lakes	7·300	0·314	717·0	12,000	13·9	—	13·9
Carisolo	—	—	1·950	473·0	10,000	6·5	30·8	37·3
	—	—	1·910	287·0	24,000	34·5	26·5	61·0
Favrio	Fiavè Lake	10·750	0·450	154·45	2,000	4·3	—	4·3
Nembia	Molveno Lake	—	12·15	55·18	14,000	12·8	26·2	39·0
			15·574	553·0				
S. Massenza	Molveno Lake	207·5—234·0	(0·956)	459·10	355,000	320·0	317·0	637·0
	Ponte Pia	1·0	8·35	202·70	44,000	36·8	71·2	108·0
Torbole	Toblino, S. Massenza Cavedine, Loppio Lakes	18·0	29·286	166·18	135,000	147·5	154·5	302·0
			0·301	154·53	—	—	—	—
			Total quantities		655,800	637·3	789·1	1426·4
Energy generated by power stations superseded by the project						5·3·0	140·0	190·0
Net output increase						587·3	649·1	1236·4

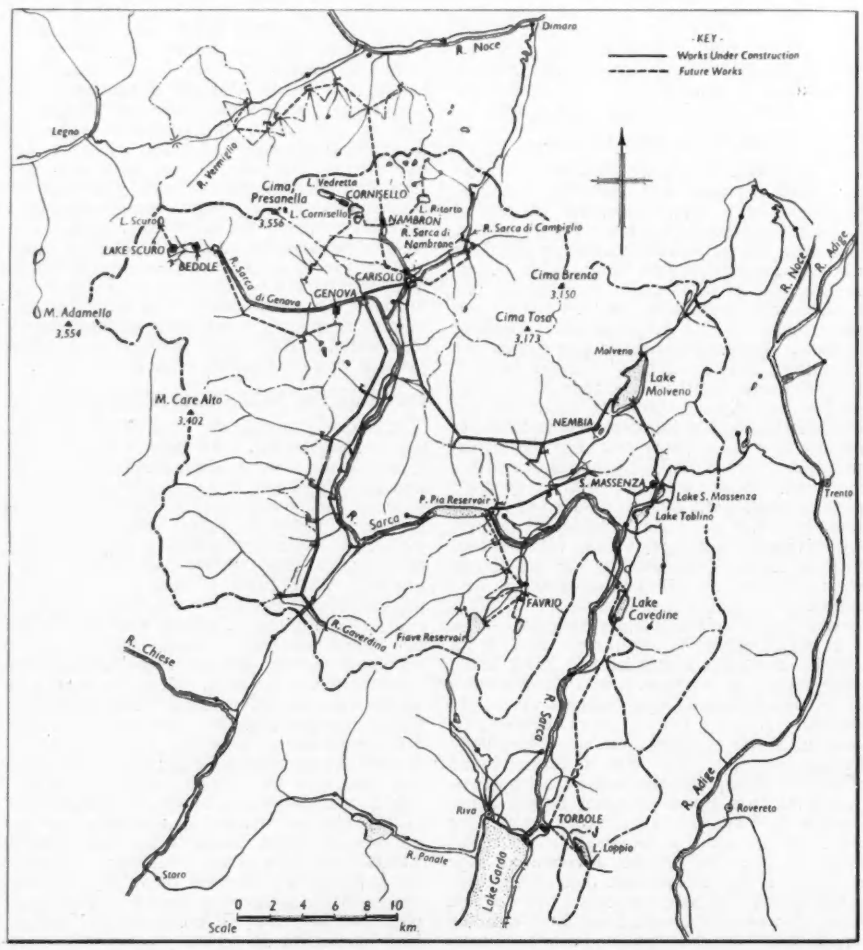


Fig. 5—The Sarca River Project

each of the shafts and the lake. The water thus pumped from the lake was used to generate power from the first two sets at Santa Massenza power station, which had been installed by the time that this stage of the work was reached. With one shaft in use for the pump discharge, a horizontal tunnel was driven from the other shaft, so

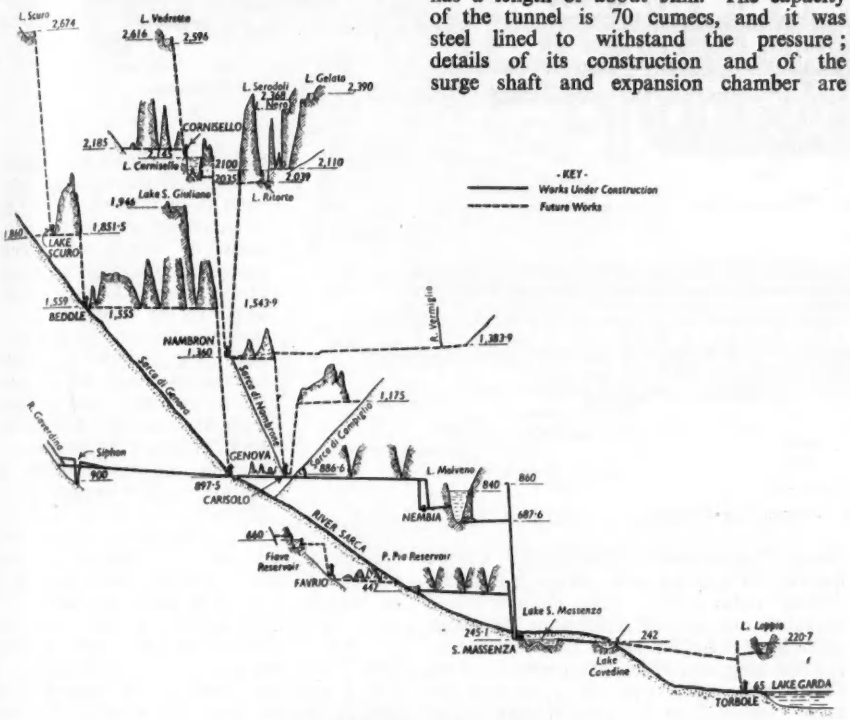


Fig. 6—The Sarca River Project

that it emerged just above the surface of the lake when the latter had been lowered as far as the permissible head on the pumps allowed. The pumps were then discharged through the new tunnel at virtually no head at first, the head against which they delivered increasing as the level dropped. At the same time a new horizontal tunnel, still lower down, was driven from the first shaft. In this manner the level was lowered sufficiently to construct an intake with an invert level of about 705, that is 120m below the original surface of the lake. In the completed work there are two intakes (at levels of 709 and 720) each with a guard gate and control gate at one of the two shafts referred to above, leading to a single diversion tunnel, which has a length of about 5km. The capacity of the tunnel is 70 cumecs, and it was steel lined to withstand the pressure; details of its construction and of the surge shaft and expansion chamber are shown in Fig. 8. The two underground penstocks were also steel lined, as shown in the illustration. They vary between 2·5m and 2·6m in diameter and have lengths of 733m and 834m.

From Lake Ponte Pia, where an arch dam 45m high has been built to provide weekly regulation with a storage capacity of 1,000,000 cubic metres, a pressure tunnel 11km long and 3m in diameter with a capacity of 15 cumecs leads through a penstock of 2·4m internal diameter to Santa Massenza power station. The arrangement in the power station for utilising these two separate diversions is referred to in the next section.

Fig. 7—Molveno Lake Pumping Station

Santa Massenza Power Station

The Santa Massenza power station will be the largest Italian hydro-electric power station when it is complete. It forms an important nodal point of the envisaged 220kV transmission network and will be used for frequency regulation, for peak load power and for seasonal integration of load, by virtue of the year to year storage envisaged at Molveno Lake, as described above. The advantages to be gained from building the power station underground are evident from a study of the site; there would have been little room for a surface structure beside Santa Massenza Lake, without some reclamation, and if such a structure had been chosen, rather difficult foundation conditions would have been encountered.

The accompanying plan, Fig. 9, shows the general layout of the power station, from which it will be seen that the two penstocks from Lake Molveno lead to four 70MVA sets, two 35MVA sets and one 5MVA set. The four principal sets each consist of a horizontal alternator with a Pelton wheel on each side of it. The two 35MVA sets are similarly disposed, but each one also incorporates a 25MW pump. The 5MVA set consists of a single Pelton wheel and alternator. The gross heads for this plant, which constitutes "Santa Massenza No. I," vary between 590m and 460m with an average of 553m.

The penstock from the second reservoir leads to a vertical Francis turbo-alternator set of 25MVA and to a 5MVA Pelton wheel set, the gross head in this case being 203m (Santa Massenza No. II). A branch from this penstock leads to the intake of the

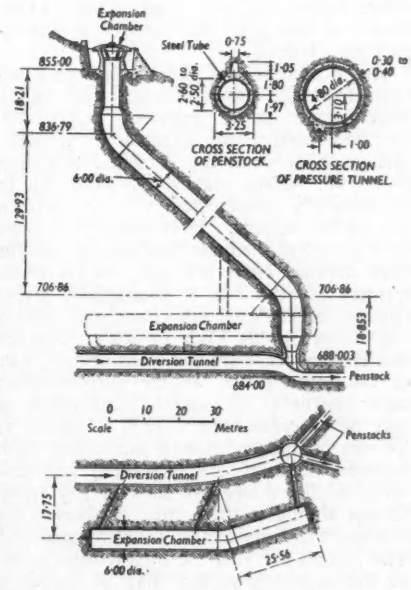


Fig. 8—Arrangement at Surge Shaft

pumps of the two 35MVA sets, so that at times, when the load conditions are favourable (i.e. at night and during holidays, during the spring and autumn when surplus water is available at the Middle Sarca intake), these two sets can be used to pump water from the lower reservoir to the higher one; the pumps thus deliver against a head equal to the difference in level between the two reservoirs.

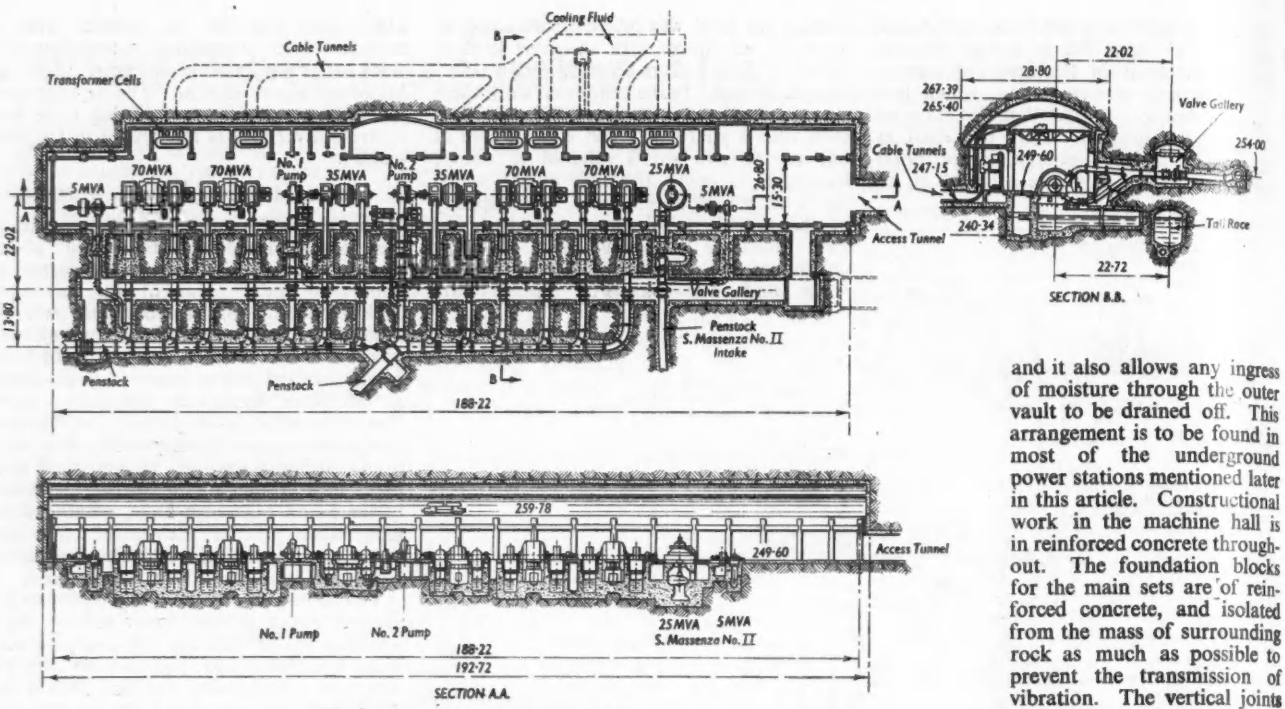


Fig. 9—Santa Massenza Power Station

The two 5MVA sets and two 1MVA sets, one of which is driven from each supply, supply power for local consumption and for station lighting and auxiliaries.

The penstocks are disposed parallel to the machine room with successive branches leading to each machine. The penstock valves near each turbine inlet, and at the central junction of the two penstocks of the high-pressure system, are rotary valves. For the great majority of their length the penstocks consist of welded steel tubes packed round with concrete and relying on the surrounding rock to take part of the pressure ; where they emerge into the power station they consist of steel pipes reinforced with shrunk-on rings of steel.

The positioning of the transformers departs from the usual practice with Italian underground power stations. Generally, the transformers are situated in a separate chamber from the principal machines or on the surface nearby if a shaft can be economically constructed to a convenient site on the surface. In this case they have been placed in the main machine hall, as the plan shows. There are five 70MVA transformers for the No. I installation, giving voltages of 15kV or 23kV, and one 5MVA transformer giving 15kV or 20kV. For the No. II plant there are two transformers, each of the same power as the corresponding turbo-alternator set. Each transformer, as may be observed from Fig. 9, is placed in its own compartment with substantial walls between adjacent compartments, and fire-proof sliding doors can seal off any transformer should it catch fire. Elaborate fire extinguishing apparatus is also provided. The tunnels carrying the high-tension cables to the switching station may be noted, as may the travelling cranes serving the machine room and valve chamber. The 230kV cables are carried for 600m through the cable tunnel to the outdoor substation, which has been constructed on the edge of Santa Massenza Lake, on a site reclaimed with spoil from the tunnelling. Four 230kV lines leave this substation.

Excavation for the power station was in good limestone or marble and presented little difficulty, even though a considerable inflow of water had to be dealt with. A large quantity of material was excavated, totalling 100,000 cubic metres. The main machine chamber has overall dimensions of about 190m by 29m by 28m high ; the access tunnel is 370m long, and of horseshoe cross section. Other major excavation works included the cable tunnels from the transformers to the switching station, the tail-race tunnel, the valve chamber next to the machine hall, and the tunnels for the penstocks and the surge shaft and chambers. The machine hall is shown under construction in Fig. 10 ; the transformer chambers are on the left.

As may be observed from the cross section in Fig. 9, a false vault has been constructed in reinforced concrete to form the top of the machine hall. The space above it serves as a return duct for the air conditioning system and it also allows any ingress of moisture through the outer vault to be drained off. This arrangement is to be found in most of the underground power stations mentioned later in this article. Constructional work in the machine hall is in reinforced concrete throughout. The foundation blocks for the main sets are of reinforced concrete, and isolated from the mass of surrounding rock as much as possible to prevent the transmission of vibration. The vertical joints between the blocks and the rock comprise a symmetrical laminated pad of five layers included for this purpose. In the centre is a strip of copper, with glass wool on each side of it and with cardboard on each side of that. The blocks are also isolated from the machine room floor with cardboard and bituminous joints. The exclusion of ground water from the completed power station was an important problem, one of the waterproofing measures adopted being the use of a layer of patented waterproof cork material 1in thick on the walls.

Santa Massenza power station makes an interesting comparison with Malgovert power station on the Isere River in France. Both are Pelton wheel installations of large size ; the installed capacity at Malgovert is less (280MW in four similar sets), but the annual power production is slightly

Fig. 10—Power Station Under Construction

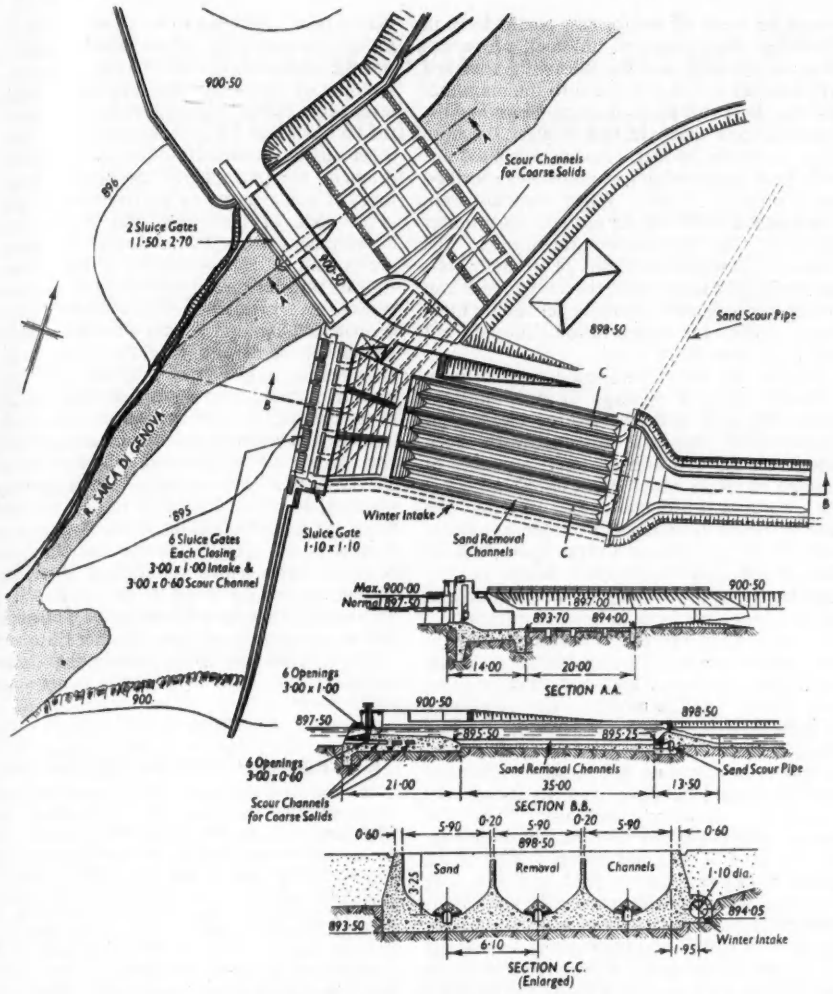


Fig. 11—Intake on the Sarca di Genova

greater (800 million kWh of firm power), but at Malgovert the more conventional system of pipelines in the open and a power station building may be compared with the underground layout at Santa Massenza.

Some of the other works of the Sarca Molveno project may be noted here. As Fig. 5 indicates, an extensive array of work remains to be carried out to complete the project. We illustrate above (Fig. 11) the intake works on the Sarca di Genova with its desilting channels. The many diversion tunnels and intake works have included some interesting technical problems, including in one case the stabilisation of excavation in clay by electro-osmosis for the construction of the intake for the diversion of the Sarca di Campiglio.

(To be continued)

Considering Powder Metallurgy

By H. W. GREENWOOD*

The engineer of to-day will be prepared to look into powder metallurgy only if it can provide some substantial advantage over other methods of production in the way of reduction of cost, easier availability of raw materials, improved properties of parts, including better physical properties, longer life and enhanced performance. Because modern materials and methods can do all these things it may be useful to consider powder metallurgy in the light of to-day's conditions. It is suggested that conditions and prices have changed very materially in the last year or so, and where changes did not appear advantageous only two or three years ago, they can now be more than justified in many cases.

AN outstanding trend of recent times has been the phenomenal rise in prices of materials, but above all, in the non-ferrous metals. Copper, lead, tin and zinc, to mention the principal four, have risen tremendously and, although a fall is to be anticipated, it will never be such as to approach the prices of pre-war days. Moreover, we now are able to recognise that our consumption of these, and equally of many less common metals, is increasing at such a pace that sooner or later we shall be compelled to consider the replacement, especially of the less abundant metals, by iron or some other substitute if we are to eke out supplies. It might be suggested that here is a very strong argument in favour of considering the substitute of powder metallurgy for other processes, bearing in mind the following points :

(1) The saving of large quantities of copper, zinc and tin by using components made of iron powder.

(2) The elimination of all scrap and waste such as are inevitable when casting, cutting, milling or other methods and especially machining, are used.

(3) The very notable reduction in stocks possible in a large establishment, of partially fabricated metal in the form of sheet, rod and bar, and consequent setting free of capital for other purposes.

(4) The much greater availability of metal powders.

(5) The easier control and more rigid attainment of fine tolerances accompanied by fully adequate physical properties that the powder metallurgical technique of to-day can ensure.

Not the least of the advantages that a change over to powder metallurgy can confer is that much more careful consideration is usually given to the design and function of parts. A usual result of this is marked improvement in design as well as notable economies in material and cost. An example may be cited, namely a cam used on a timing device, which had previously been made of an alloy steel heat treated to a hardness of Rockwell C.60, and then highly polished because, so it was said, it could not be adequately lubricated. It was replaced by a cam pressed from a normal soft iron powder and oil impregnated. It performed its duty excellently, it showed much less wear and so gave longer life and it cost just about one-fourth as much as the alloy steel part. There are still many small parts used in industry that are produced by machining from blanks, but every year sees their number reduced by the use of powder metallurgy. A well-known example is the oil pump gear the first operation in the production of which is the machining away of some 60 to 65 per cent of the metal comprising the blank. Here the advantage of powder metallurgy is very notable, for there is no loss of metal. If a part calls for four ounces of iron, or copper, or bronze, then four ounces is used, neither more nor less. In establishments of any size, the tie-up of valuable metal can be illustrated by a single example in which one fair-sized factory reduced scrap production by some 5 million pounds in one year by changing over to powder metallurgical methods. It would be wrong to think that economies are confined to saving metal. Time and man-power are also involved as was particularly experienced in the great munition factories in the United States during the war. An example of time saving was in the production of a bronze gun-sight bracket, which was pressed in twelve seconds, whereas contour machining of the piece required two hours. An example of man-power economy was the saving of 5 million man-hours in 1942 by the Chrysler Corporation on the production of 20,000 sets of a particular gun mount, in which each set comprised ninety parts.

Other somewhat similar examples could be cited in which economies on perhaps a somewhat smaller scale had been accomplished both in this country and abroad, and a general conclusion would be that there is room for a much greater extension of the powder metallurgical technique than has so far taken place. An extremely interesting aspect of post-war progress has been the extent to which new developments have taken place, both at home and abroad, not, as might be expected, in the simpler and more obvious direction of applying powder metallurgical methods in general manufacturing practice, but in the more highly specialised and difficult field of hard metals, and high-temperature resistant alloys. Another notable trend is that whereas up to the outbreak of the last war, progress was largely along empirical lines, to-day the approach is often from the theoretical side, and the

* Powder Metallurgy Limited, London.

analyst, the crystallographer, the physicist and physical chemist are all called upon to co-operate with the metallurgist. One result of this has been a notable addition to our knowledge of the hard metals, an extension of investigations to include the behaviour and use of ceramics among refractory materials, extended researches on the influence of minute quantities of impurities on alloys and metals, and the development of refined methods of production including particularly repressing and double sintering.

One result of such work has been the production of unalloyed sintered steels having tensile strengths of up to 40,000 lb per square inch, and elongations of 32 to 35 per cent. Components made in these steels have a dimensional accuracy and a surface finish which probably surpasses any product made anywhere else. This is a Swedish enterprise and involves the making of the company's own iron powder. In Germany, a most interesting development has been in the sintered magnet where in one factory production is of the order of 20 tons a month, and what is of even greater interest, the magnetic qualities of the magnets produced are claimed to be absolutely identical with cast magnets while the mechanical properties are substantially improved. Another development offering great promise in the future is the employment of infiltration technique, whereby the pores of a metal compact are filled, or infiltrated, with another metal or alloy having an appreciably lower melting point than that of the porous compact. This technique has already received important applications. One noteworthy example is the production of millions of jet-engine compressor blades in the U.S.A., by infiltrating iron compacts with a molten copper alloy. The blades have proven very satisfactory in service and highly competitive with forged blades produced from 12 per cent chromium steel previously used for the same purpose. Another example was the replacement of a malleable iron casting by high-strength copper-impregnated gears in the gear train of an automatic washing machine, where the saving ran to between 60 and 70 per cent. A very notable effect of infiltration is the increase in density accompanied by remarkable increase in the tensile strength of the parts. An average simple iron compact may have a tensile strength of from 4 to 10 tons per square inch; a steel compact straight pressed and sintered gave a tensile strength of just over 16 tons per square inch, but when infiltrated with 10 to 12 per cent of copper, this figure rose to 45 tons per square inch. There is the possibility of utilising age-hardening or precipitation-hardening alloys for infiltration and this opens up some very valuable possibilities. A reasonably average case may be cited in which the iron compact after sintering gave a tensile strength of 7 tons per square inch. After coining, the strength was 9 tons, after simple infiltration 27 tons, and after heat-treatment 41 tons per square inch. Even more favourable results can be had by using precipitation-hardening alloys. It has also been found that infiltrated parts can be given extra protection by plating or chromising, and can then far outlast stainless steel in corrosion resistance, as well as under the salt spray or alternating humidity tests.

It will be obvious that the technique of infiltration has dealt effectually with the old time complaint that powder metallurgical parts lacked strength. What is perhaps more important to-day is not the querying of the ultimate strength of the parts that can be supplied, but making sure that excessively high properties are not asked for unless they are really necessary. In this connection it may be emphasised that much more use could be made of test-pieces, particularly in deciding the range of physical properties that are essential, and that should be specified and can act as a useful guide to the manufacturers. It is still possible to come up against specifications that are meaningless, because they can never be met. A case was cited not very long ago in which an angle was specified to 1 minute of arc. When samples were checked the error was as much as 44 minutes of arc ! In the same category are the requests for tensile strengths of so many tons to the square inch, when the actual loads can better be measured in ounces per square inch. Such cases of exaggeration should not occur in these days.

One of the very promising aspects of infiltration alloys of the age or precipitation-hardening type is the very large measure of control that appears possible with such alloys by the addition of small amounts of foreign elements which can exercise an effect on the physical properties, and especially the rate of reaction of the age-hardening alloys, out of all proportion to the quantities of foreign elements involved. Work in this field is, as yet, in its infancy, but the potential value of such methods is beyond question.

Considering powder metallurgy to-day one cannot overlook the large and increasingly important subject of high-temperature resistant alloys. At the moment, the metallurgy of such materials may be considered as being in a transition stage, and this applies both to alloys and metals produced by classical metallurgical procedure, and to those produced by powder metallurgy. For the moment we appear to have an almost embarrassing mass of data and material upon which one can only say that no final, and only very few temporary, conclusions can be arrived at. Indications are that materials other than the known metals and their alloys are almost certain to be necessary if we are to produce turbines and jet engines capable of standing up to the temperatures that obviously can and will be met in developments which can already be seen ahead. Thus, it would appear that refractory materials, which may be oxides, carbides, borides or silicides, will almost certainly be used to a greater or lesser extent, and they can only be manipulated by a powder metallurgical technique. To what extent they will be required is not at present known, nor is it clear whether they will perform more than a protective function either as a coating on the exterior of parts or as a constituent of the more solid parts of an apparatus or engine. It is interesting to note that a ceramal coating of 80 per cent by weight of chromium and 20 per cent of frit have been used on blades comprising 80 per cent titanium carbide and 20 per cent cobalt, and allowed of extended operation of the blade at a temperature of 980 deg. Cent. A great deal of investigations have been carried out based upon titanium carbide, more particularly solid solutions of chromium carbide in titanium carbide cemented with nickel or cobalt. Another solid solution was based on titanium carbide with 15 per cent of other carbides. Yet another solution suggested is compacts of tantalum powder, shaped, and then sintered *in vacuo* at 2200 deg. Cent., and finally chromium plated and heat-treated at the forging temperature of chromium and hot-forged. Obviously, most of these methods are of mainly experimental interest, having as their main object the gaining of further experience on the manipulation and the properties of these and other refractory materials. Some idea of the direction in which all this work is leading may be gathered from the turbine blades, hot extrusion dies for light alloy sections and other developments in which titanium carbide base ceramals play a part. Although this country does not indulge in any tremendous developments in powder metallurgy, there has been and is a volume of work of the highest technical level being carried out and we have no reason to be ashamed of the position we hold, especially in the aircraft industry. While at the moment the part played by powder metallurgy is not as large as we could wish, there is no lack of most excellent experimental development work being done. Where we are behind in development is in the application of powder metallurgy to what has been called the " bread and butter " productions of iron and steel parts which form the major output of small and medium parts in any engineering shop. It is with this particular class of material and the senior staff engaged in its production that the value and importance of considering powder metallurgy as a real factor in engineering should appeal. There is now a very large and a growing practical technical literature on the subject; there are sound textbooks available and there should be no question as to the economic benefits that a wider application of powder metallurgy would bring in its train. It is very certain that the advantages of such application are recognised in most other European lands, just as they have been in the United States.

Corrugated Concrete Shell Roofs

On Tuesday, February 10th, a paper with the above title was presented to the Institution of Civil Engineers by Mr. J. H. de W. Waller and A. C. Aston, which gave an interesting review of the method of construction known as the " Ctesiphon " roof. Such roofs are formed by erecting centring ribs of catenary shape at specified distances apart, and covering them with some flexible shuttering material, such as hessian. A thin layer of concrete is applied to the hessian, which thus sags between the ribs. When the concrete sets, therefore, a corrugated arch shell is formed. Mr. Waller pointed out in the paper that the simplicity of the arch was an attraction in itself, and he thought that the arch should be rescued from the comparative obscurity into which it had been relegated by the preference given to beams and girders. The system of construction which formed the subject of his paper had been inspired by the Great Arch of Ctesiphon about 15 miles from Baghdad, which he thought was the first column-free rectangular building of importance ever built, being 112ft high and nearly 90ft in span.

Mr. Waller continued by stating that the reason for the catenary arch was simply that the dead load stresses were purely compressive. Bending moments due to live load could not be eliminated however, even in an arch ring, and an adequate moment of resistance had to be provided. To obtain this by thickening the arch ring, as had been done in the past, was, he contended, too expensive, and the use of simple corrugations by a cheap and practical method had been the aim of his work. The buildings so far constructed by this method, in eighteen countries, totalled nearly a million square feet in covered area, and had spans of up to about 60ft. However, Mr. Waller pointed out that a corrugated true arch 700ft in span and 4in thick was practical and economical.

The second part of the paper was devoted to theoretical considerations of the ctesiphon roof, and was written by Mr. Aston. An appendix described briefly a ctesiphon design for an aircraft hangar of 310ft span.

Microwave Test Equipment.—A " tailored " range of X-band test equipment for microwave test benches is being developed for the Admiralty Signals Research Establishment, by the Plessey Company, Ltd., Ilford, Essex. The equipment comprises high- and low-voltage stabilised power supplies, a modulator and a selective amplifier. It should prove useful to those who are engaged in microwave measurements involving standing-wave measurements, frequency calibrations and similar work.

The Proton Synchrotron at Birmingham University

No I

A new particle accelerator, known as a proton synchrotron, for nuclear physics research, is nearing completion at Birmingham University, under the direction of Professor P. B. Moon. It may be recalled that the project was originated by Professor M. L. Oliphant with the financial backing of the Department of Scientific and Industrial Research. In the following description we give an outline of the design and construction of the proton synchrotron : most of this work was carried out by members of the University staff.

THE proton synchrotron, which is now being built in the Physics Department of Birmingham University, is one of the younger members of a growing family of particle accelerators used for research work in nuclear physics. This synchrotron is designed to accelerate protons, as distinct from the much less massive electrons. To the physicist, therefore, it is of interest because it is perhaps the most powerful known means of investigating the properties of the nucleus by direct bombardment, inasmuch as the relatively massive proton is likely to be a more effective projectile than the electron.

To the engineer the proton synchrotron with its associated equipment is a completely unorthodox project. It embodies an exceptionally large electromagnet, weighing 810 tons and built to produce a rigorously specified fluctuating magnetic field. It had to be designed from first principles and it had to be tailor-made without the benefit of data obtained from either a scale model or a prototype. Apart from the manufacture of the raw materials of the magnet and the installation of various plant auxiliaries, all the work of design and erection is being carried out on site, using the technical resources of the University.

In this article we propose to describe some of the more interesting engineering aspects of this work, without referring to nuclear physics, except to introduce a few elementary ideas that may help the engineer to appreciate the main factors governing the design and construction of the synchrotron.

The familiar present-day concept of atomic structure is that all materials consist of a massive nucleus around which one or more electrons move in different orbits. All the electrons are identical, carrying the same negative electrical charge and having the same very small mass. The nucleus, which is our immediate concern, is pictured as being an agglomeration of at least two kinds of particles—the proton, which has about 1840 times the mass of the electron, and carries a positive charge balancing the negative charge of the electron, and the neutron, which has no charge but is of about the same mass as the proton. To preserve the simplicity of this picture no mention need be made here of other particles, whose existence within the nucleus is postulated by physicists.

For our present purpose the main consideration is that the attractive forces binding the nucleus together are extremely strong. To disrupt the nucleus by bombardment requires missiles with a high energy content and, to produce such missiles, the physicist needs powerful particle accelerators.

Without attempting to trace the evolution of particle accelerators it is convenient to start by outlining the principle of the cyclotron, from which the proton synchrotron is directly descended. Essentially the cyclotron consists of a pair of hollow "D"-shaped electrodes, forming the two halves of a flat, cylindrical box split along a diameter and separated by a small gap (Fig. 1). The electrodes are mounted in a vacuum chamber symmetrically placed between the poles of a powerful electromagnet. A source of ions (positively charged) is placed centrally within the electrodes, which are connected to a high-frequency voltage source.

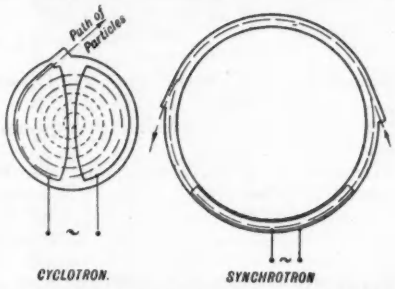


Fig. 1—Principles of the Cyclotron and Synchrotron

Each ion that is emitted is attracted to the electrode that happens to be negative at the time but the effect of the transverse magnetic field is to make the moving ion travel in a circular path. The frequency of the a.c. supply to the electrodes is made such that, as the ion is emerging from one electrode, the polarity reverses. The ion is then attracted to the other electrode, inside which it continues its circular path until it reaches the gap, when the polarity is again reversed, whereupon the whole cycle is repeated.

At each reversal the ion receives a fresh energy impulse as it crosses the gap and each increase in energy causes an increase in the radius of the ion's orbit. Each ion, therefore, moves in a series of semi-circular paths of increasing radius, but, in effect, its path may be regarded as a spiral as indicated in Fig. 1. By the time the ion approaches the circumference of the vacuum chamber it will have traversed the gap a large number of times and acquired a corresponding increase in energy.* At this stage the ion is deflected through a slot in the electrode and impinges on a target incorporating the material that is to be bombarded.

There are various physical limitations to the particle energy that can be produced by the cyclotron. Of these limitations the most obvious practical one is imposed by the fact that, other things being equal, increase in energy involves increase in the radius of the path described by the particle. The particle energy W at first increases in proportion to the square of the diameter D of the pole piece: so, to double the energy, one must increase the magnet diameter by $\sqrt{2}$ and the volume by about $2\sqrt{2}$. The 175MeV Harwell cyclotron weighs 670 tons, the Chicago 450MeV machine weighs about 2000 tons. Beyond a few hundred MeV, however, the energy increases more slowly, ultimately becoming proportional to D and not D^2, and double energy then requires an eightfold increase in magnet weight.

* In practice the energy imparted to the ions is usually expressed in "million-electron-volt" units, or MeV—one million electron volts signifying the amount of energy acquired by an electron in traversing a potential of one million volts.

The Synchrotron

To obtain the higher energy levels (such as 1000MeV, which is envisaged at Birmingham University) attention was, therefore, turned to the synchrotron, which, for a given output, is physically much more compact than the cyclotron. In the synchrotron, as in the betatron, the particles, instead of being accelerated in a spiral path, are enclosed in an annular vacuum chamber ; there they are constrained to move in a circular path by increasing the magnetic field uniformly with the increase in particle energy. Referring to the right-hand diagram, Fig. 1, the principle of operation, briefly, is as follows.

Particles are injected tangentially into the vacuum chamber. The magnetic field is of the right strength to compel the particles to move in the circular path provided by the vacuum chamber. During each circuit of the vacuum chamber the particles pass through an accelerating electrode fed with r.f. power from which they receive a pulse of energy. This rise in energy would tend to increase the radius of the particle orbit but the effect is counteracted by a corresponding increase in the magnetic field strength. Accordingly the particles follow a circular orbit, receiving two pulses of energy from the accelerator at each circuit. Since the speed of the particles rises with each pulse of added energy, while the increasing field maintains the circular orbit, the time to complete the circuit diminishes progressively and the radio frequency must be correspondingly increased.

Although the detailed problems involved in the r.f. timing control and of the design of the magnet are outside the scope of this article, it is necessary to have some conception of the scale of the accelerating process. For example, referring specifically to the Birmingham synchrotron, the whole process of acceleration occupies about one second, during which each particle acquires a maximum energy of 1000MeV after 7×10^5 complete circuits, the mean time of each circuit being $^1/_7$ microsecond. During the acceleration period of one second the magnetic field is required to rise from zero to 12,500 gauss. The engineering design of the magnet system was governed by a number of stringent requirements. Briefly, the magnetic field must vary accurately with time during the acceleration period, it must be uniform within narrow limits over the circumferential path of the particles, while its radial distribution must be precisely controlled to stabilise the orbit of the accelerated particles. Some of the effects of these requirements will be considered later in this article.

Design and General Arrangement of Magnet

The elevation of the synchrotron magnet is shown in Fig. 2. Viewed in plan, the magnet consists of a circular ring, 32ft in diameter, the core being built up of a large number of radially disposed vertical plates, with taper plates at intervals to produce the overall circular plan form.

To produce the required field strength of 12,500 gauss (maximum) across the air gap occupied by the vacuum chamber, there is a winding comprising twelve circular coils,

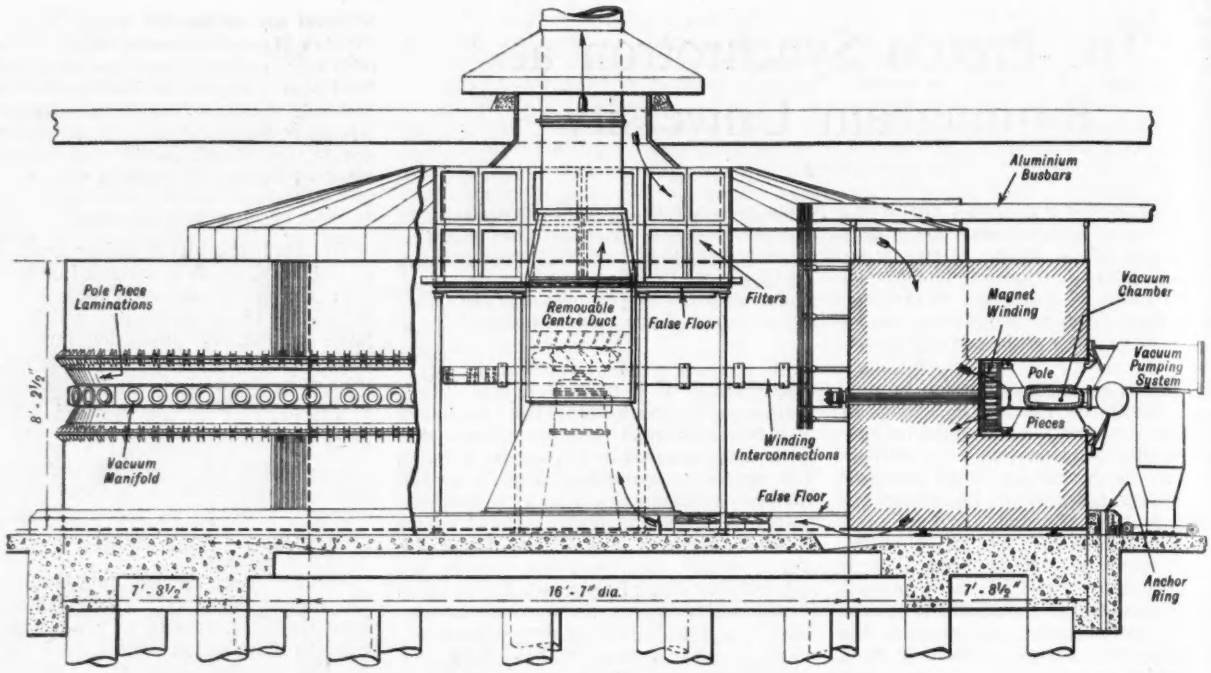


Fig. 2—Part Sectional Elevation of Birmingham University Proton Synchrotron

the magnetising current (12,500A peak) being obtained from a specially designed motor generator set housed in a separate plant room.

Forced air ventilation is provided, to dissipate the heat generated by an iron loss of 50kW in the synchrotron magnet and a copper loss of 182kW in the magnet coils. The cooling system is indicated in Fig. 2 by arrows showing roughly the path followed by the ventilating air before being exhausted by the centrally placed motor-driven fan. The ventilating system and the problems involved in providing magnetic shielding for the motor are discussed more fully later.

The diameter of the magnet (32ft) and the main dimensions of the magnetic circuit were determined from first principles by the physical laws of particle acceleration taken in conjunction with the working figure of 12,500 gauss for the maximum flux density conveniently attainable in the interpolar gap.

Two main factors decided the width of the interpolar gap. The first was the need for space to encompass the inevitable vertical oscillations of the particles above and below the median plane. The second consideration was the space required to accommodate the top and bottom walls of the vacuum chamber with reasonable clearance to the magnet pole faces. In the present installation the designed gap is about 8in.

Laminated construction of the magnet was necessary for two reasons. First it was necessary to reduce the iron losses associated with the rapidly changing flux density during the operating cycle and, more particularly, to minimise the eddy currents which would otherwise upset the designed distribution of the flux density in the air gap. Secondly, it was essential to reduce to manageable proportions the physical task of erecting the magnet.

For manufacturing convenience, ½in thick mild steel plate (0·08 per cent carbon) was decided upon and taper plates having half the radial width of the main plates were introduced at regular intervals to achieve the required circular build-up. " U " section distance pieces were tack-welded horizontally across the centre of the main plates at intervals round the magnet to serve as baffles for the ventilating air. To reduce eddy currents and to prevent corrosion, the flat faces of the plates were bitumen painted before erection.

The design of the foundations and the erection of the 810-ton magnet were determined mainly by the overriding need for rigidly maintaining magnetic uniformity along the whole circumferential length of the air gap. Accordingly, it was decided to impose a dimensional tolerance of ±0·010in on the faces of the annular channel, housing the upper and lower pole-piece rings (Fig. 2). To achieve this tolerance over the 100ft peripheral length of the air gap channel in the main magnet involved great accuracy during erection ; to maintain the tolerance throughout so massive a structure it was necessary to provide very rigid foundations, in view of the fact that the Nuffield laboratory which houses the synchrotron is sited on sandy subsoil.

As shown in Fig. 2 the magnet is built on a circular reinforced concrete raft, supported on 28ft cast-in-situ piles, arranged in an outer circle of fifteen piles and an inner circle of eleven piles. Eleven channels, one of which is shown in Fig. 2, were formed in the upper surface of the foundation block to constitute part of the ventilating circuit. To support the magnet plates steel rails were grouted into the foundation block, as shown in Figs. 2 and 3. Adjustment for height and level of each plate during erection was made with the help of steel wedges interposed between the plate and the supporting rails.

Erection of the magnet presented no major problems in mechanical handling. To move the ½-ton plates into position a radial gantry was set up with a circular track for the " A "-shaped support, which can be seen at the extreme right of Fig. 3. To equalise the loading on the foundations, erection of the magnet plates was begun at two diametrically opposite points and proceeded in the same

Fig. 3—Early Stages of Magnet Core Building Operations

sense from both starting points, as can be seen from Fig. 3.

Erection of Magnet

Unusual erection methods were employed in the adjustment of each plate to ensure accuracy of alignment throughout the annular channel housing the pole-pieces. To achieve the required standard of magnetic uniformity in the annular gap the machined upper edge of the "window" in the first plate was used as a datum and each subsequent plate was adjusted to bring its corresponding edge within ±0·010in of the datum. Briefly, therefore, the aim was to make the roof of the channel level and true. It was important to avoid sudden irregularities as well as smooth undulations in the surface, since the protons, during acceleration, are particularly sensitive to any violent asymmetry in the magnetic field.

To attain the desired positional accuracy at points as much as 30ft apart, a form of hydrostatic level was developed, based on a method of levelling that was used by the ancient Egyptians in building the Pyramids. Essentially the system comprises a ring water main, connected by rubber tubing to an indicator (Fig. 4*a*) mounted on the first plate, serving as a reference point, and a similar indicator on a diametrically opposite plate, each indicator resting on a straight-edge datum bar.

The indicator is simply a water-tight housing for a ground and hardened stainless steel needle seated on a hardened steel ball, which rests on the datum bar. The needles in both indicators are of equal length to within 0·0002in. A simple bellows (see Fig. 4*a*) allows the water level in the two indicators to be raised or lowered. The direct and reflected images of the needle tip are viewed through a simple telescope, as shown. Then, as the water surface approaches the tip of the needle, the two images of the tip converge and meet when the tip breaks the surface. Since the water level must be the same, under static conditions, the datum bars at the two stations will be level when image coincidence is obtained in both indicators.

Briefly, the levelling operations consisted in setting up the datum bar with the help of a dial gauge and spirit level at the reference station and repeating the same gauge setting at the remote station. The water level was then altered by adjusting the bellows until coincidence was obtained on the reference indicator. Then, at the remote station coincidence was obtained by adjusting the wedges between the magnet plate and the supporting rails. Having thus established identical datum conditions, it was possible to proceed with the erection of the plates simultaneously at both stations. At each station the plates were adjusted in position with the help of the jig shown at (*b*), Fig. 4 and in Fig. 5. The jig consisted

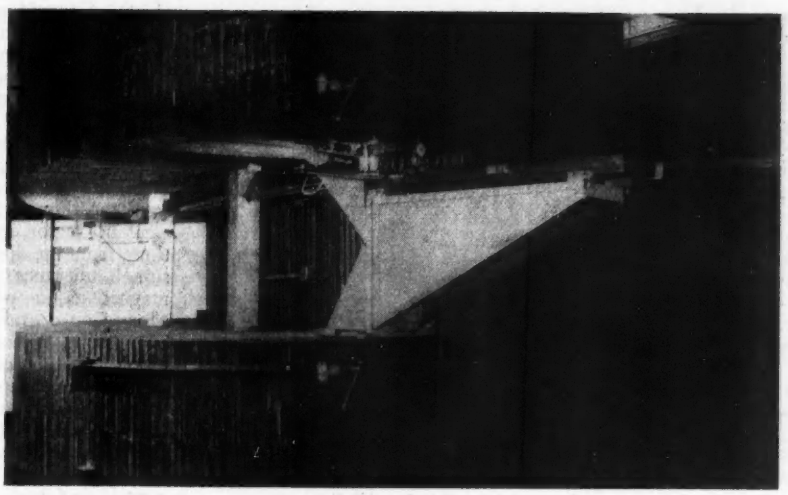


Fig. 5—Hydrostatic Level in Use

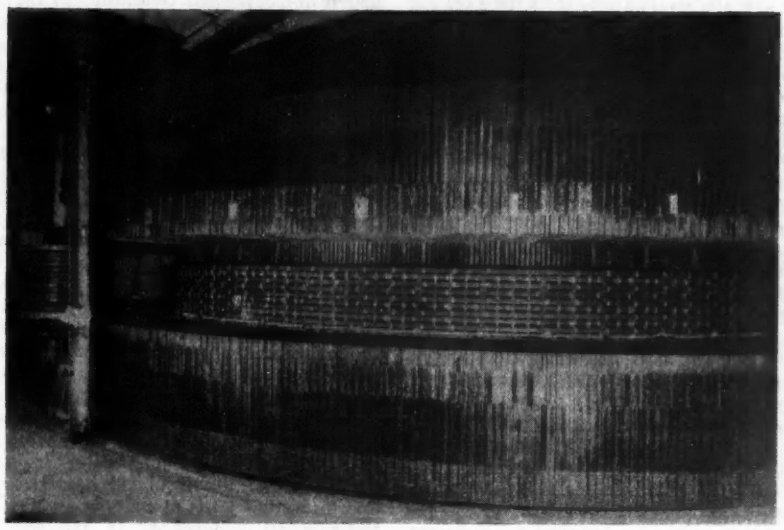


Fig. 6—Part-Wound Magnet Showing Winding Tackle

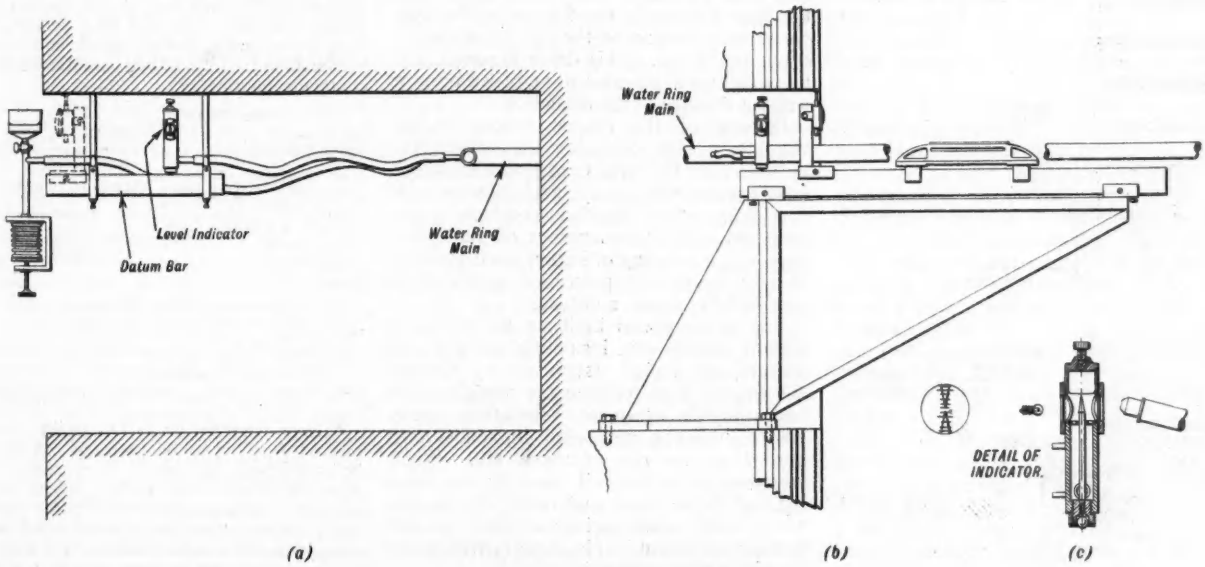


Fig. 4—Hydrostatic Levelling Arrangements

Fig. 7—First Coil Section and Top Junction Box

essentially of two adjustable datum bars with a Watts level capable of sitting on one bar as at (*b*), Fig. 4, or of straddling the two bars, as in Fig. 5. After the datum bars had been adjusted the dial gauge provided the means of checking the adjustment of each plate as it was placed in position. The clamps used to hold the plates ready for tack welding after adjustment can be seen in Fig. 5. To avoid parasitic current effects, all the tack welding was done on the surface of the magnet outside the air gap.

By using the upper surface of the magnet gap as the datum, the subsequent assembly of the pole-pieces was simplified, since any packing that might be necessary could be done more easily on the lower surface. The windows were machined over-size in batches (i.e. 27·5in+0·010in overall height) during manufacture, to ensure that the taper plates would constitute the "peaks" and the main plates the "hollows" in the profile of the lower surface of the magnet gap.

After the plates had been erected and band welded to complete the magnet core, a survey of the gap was carried out with the object of providing a basis of comparison for any future surveys that might be undertaken later to establish the stability of the complete structure. The first survey yielded only one unexpected result. Although there were no major deviations from the dimensional tolerance, the magnet as a whole showed an overall tilt of 0·005in, measured along one diameter. No immediate explanation for this deviation could be offered except that the unequal subsidence coincided with a prolonged period of drought. A second survey, made some months later, after rain had restored normal conditions in the subsoil, showed that the tilt had disappeared.

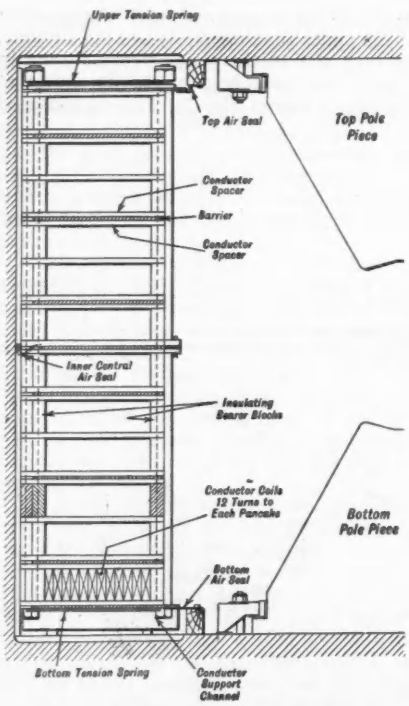


Fig. 8—Winding and Part of Air Gap

Magnet Winding

Chronologically the next main operation was that of building up the winding in the annular space between the magnet core and the pole-piece assembly. An arrangement of twelve pancake coils was decided upon, the winding being divided into six sections of two coils each.

The first consideration was the method of arranging the current lead-in from the busbars, through the magnet core and into the coils of the winding. Inevitably the lead-in would introduce a sudden irregularity in the magnetic circuit and it was clear that the use of a single feed point, carrying a current of 4000A per pair of coil sections, would cause local magnetic saturation. To reduce this effect it was decided to have three feed points, disposed symmetrically 120 deg. apart, and to use insulated coaxial "go" and "return" leads at each feed point. At these points connections to the coils are made through junction boxes, one of which is shown in Fig. 7. Because of the difficulty of ventilation, these junction boxes are water-cooled.

The coils were wound on the magnet from a cable drum mounted on the gantry, which can be seen on the extreme left of Fig. 6. The decision to use pressed stranded cable (392/0·036) for the winding was dictated by the fact that space restrictions in the synchrotron room limited the size of the cable drum to 3ft 6in. This drum diameter was too small for solid cable to be coiled upon it without damage to the insulation.

Because of the limited space for the winding, a high operating temperature (of the order of 100 deg. Cent.) was envisaged and, Empire tape being unsuitable for such conditions, the stranded conductor was insulated with three lappings of 4mil glass tape with a covering of impregnated asbestos to give mechanical protection to the glass tape and to exclude moisture.

The winding was built up as shown in Figs. 7 and 8 with insulating barriers and spacers of Tufnol (supplied by George Ellison, Ltd.) to separate the pancake coils and provide adequate ventilating space. As the winding proceeded the coils were corded at intervals of about 6in. When complete the whole coil assembly was compressed by an inner and outer ring of tie-bolts, with radial springs at the top and bottom, as shown in Fig. 8, to distribute the clamping pressure evenly.

It will be seen from Fig. 8 that the complete winding is free to expand, while the central and outer air seals of canvas (doped with heat-resisting cement) constrain the ventilating air to follow the channels roughly indicated in Fig. 2. Before finally clamping the winding each pair of pancake coils was given a temperature run, up to 100 deg. Cent., by passing current of 600A for one hour. The stranded cable for the magnet winding was manufactured and supplied by the London Electric Wire Company and Smiths, Ltd.

Aluminium strip was used for the busbars supplying current to the winding, as shown in Fig. 2. For the horizontal runs three 6in by ⅛in strips were used. For the vertical runs the current loading was reduced by using four strips of the same size.

(To be continued)

A Coating Alloy for High-Temperature Use

At present, the various alloys used for valves, valve seat faces, or completely coated heads, either fail from lead oxybromide attack when the valve temperature exceeds a critical figure, or from mechanical weakness at these elevated temperatures, or a combination of both. Rolls-Royce, Ltd., has recently developed a new coating alloy which is now being used regularly on valves in civil aircraft engines. The use of a coating of this alloy on the valve head and seating has increased the period between scheduled valve overhauls to 1000 hours and even after this time only a small proportion of valves are withdrawn from service. The manufacturing and marketing rights have now been acquired by Deloro Stellite, Ltd., Birmingham.

This alloy, known as C.26, has a nickel base containing chromium, aluminium, molybdenum and other minor additions. Although hard, the alloy is not brittle under the repeated impact given to a valve face and does not crack radially under the time/temperature stresses imposed by high-power engines. The alloy is used on inlet valves owing to its excellent resistance to the abrasive action of the products of combustion of leaded fuel. The better wearing characteristics of C.26 result in a very low loss of tappet clearance. This is an immediate economy in terminal maintenance, for large aircraft may have up to 192 valves to be checked and readjusted when necessary.

The alloy resists oxidation at all temperatures up to 1250 deg. Cent. (the drop in pressure measured after six hours in a closed system containing C.26 and oxygen or air at this temperature is negligible). Provided that the iron content of the alloy is kept below 1 per cent, it is highly resistant to lead oxide and lead oxybromide at temperatures up to 800 deg. Cent., and above this temperature it is not safe to run modern highly stressed exhaust valves for long periods. The alloy is resistant to molten caustic soda and has been used in the form of cast containers for fluxes containing fluorides.

Some Properties of C.26 Alloy

Melting range	1280–1360 deg. Cent.
Density (cast bar)	7·5 to 7·6gms./c.c. at 20 deg. Cent.
Mean coefficient of thermal expansion (20–800 deg. Cent.)	14·9 to 15·2 × 10^{-6}/deg. Cent.
Thermal conductivity (800 deg. Cent.)	3·2/3·4 × 10^{-4} c.h.u./in/sec
Ultimate tensile strength (aged):	
20 deg. Cent.	60–70 tons/sq in
800 deg. Cent.	42–48 tons/sq in
Hardness D.P.N. (30kg) at 20 deg. Cent.:	
As cast	390
Aged 16 hours at 700 deg. Cent.	490–525
Aged 16 hours at 800 deg. Cent.	400–440
At 600 deg. Cent.	420[2]
At 800 deg. Cent.	350[2]
Alternating bending test in contact with lead oxybromide at 700 deg. Cent.	±12·8 tons/sq in safe stress for 40 × 10^6 reversals

C.26 is deposited on to I.C. engine valves by means of the oxy-acetylene torch. A flux may be used if preferred, but no intermixing with the base metal must take place. Where the iron content is not critical the arc welding process is used, and casting by normal commercial methods does not present any difficulties. The alloy has a fine structure and fracture, and is machinable without undue difficulty.

Hydraulic Servo - Mechanisms

THE INSTITUTION OF MECHANICAL ENGINEERS

A CONFERENCE on Hydraulic Servo-Mechanisms, arranged in conjunction with the Hydraulics Group, was held at the Institution of Mechanical Engineers last Friday.

At the first session the following papers were presented :—

AN INTRODUCTION TO HYDRAULIC SERVO-MECHANISM THEORY
By H. G. CONWAY, M.A., M.I.Mech.E., and E. G. COLLINSON, B.Sc.

VARIABLE HYDRAULIC PUMP SERVOS AND A METHOD OF IMPEDANCE TESTING
By C. D. WATSON, B.Sc. (Eng.)

VARIABLE-STROKE PUMPS FOR POWER TRANSMISSION—SOME DESIGN CONSIDERATIONS
By T. E. BEACHAM, B.Sc. (Eng.), M.I.Mech.E.

An abstract of the first-mentioned paper is printed on page 294 of this issue.

At the second session the following papers were presented :—

HYDRAULIC SERVOS
By R. HADEKEL, B.Sc. (Eng.), A.M.I.Mech.E.

SOME INDUSTRIAL APPLICATIONS OF HYDRAULIC SERVOS
By T. BRADING, A.M.I.Mech.E., and G. PARKS

SOME DESIGN CONSIDERATIONS OF HYDRAULIC SERVOS OF JACK TYPE
By N. F. HARPUR, M.A.

DISCUSSION

Mr. J. M. Ford said this was an age of electrics and electronics, but the great and varied developments in electrical technology ought not to obscure the fact that there were frequently alternative and often superior solutions to problems, including many in the realm of automatic control. The hydraulic servo was a case in point, and when this type of mechanism was correctly designed and applied its simplicity and performance were, as Mr. Hadekel said at the end of his paper, in many cases unmatched by any comparable apparatus. A characteristic difference between hydraulic machines and their electrical counterparts was the very much higher ratio of torque to moment-of-inertia obtainable with the former. This was fundamental, and the unfavourable position of the electrical machine in this respect was due firstly to the weight of copper and iron required to produce the magnetic field, and secondly, to the very low value of what might be called the "working stress" of the field. Some indication of the relative smallness of magnetic forces was given by the fact that the tractive force between a magnet pole and an armature separated by an air gap in which the flux density was 10,000 lines per square centimetre was less than 60 lb per square inch. This was very low compared with the "stress" or pressure which could be sustained by the working fluid of a hydraulic machine ; values up to several thousand pounds per square inch were common. This torque to moment-of-inertia ratio was specially important in large high-power servo applications involving the acceleration of heavy masses. By employing hydraulic drive the total kinetic energy of the system whilst in motion could often be not much more than half that involved in an electric drive, and hence the power demand during acceleration was correspondingly less. At the other end of the scale, namely, in miniature servos of fractional horsepowers, other considerations arose in the comparison between electric and hydraulic devices. For example, in tiny hydraulic machines there was usually considerable viscous friction, and this, combined with the low inertia, very often provided sufficient natural damping to permit of dispensing with special stabilising networks.

There was, of course, a very wide range of problems in which there was little to choose between the electric and hydraulic solutions, and where, although each type had its advantages and disadvantages, the overall result was the same in each case. On the other hand, there were problems for which one or the other definitely gave the better result. In many such problems there was an indisputable case for the hydraulic servo, and the Institution had performed a valuable service in providing this opportunity for ventilating the subject.

It was no secret that the Royal Navy was a large user of high-performance hydraulic servos. The range of powers covered by those servos was very wide, stretching from high precision miniature devices handling a few watts of power up to large servos with outputs of several hundred horsepower. A feature common to all those servos, and one on which he would like to hear the views of the authors, was that they all had two or more stages of hydraulic amplification. In the case of small servos this might be thought to be an extravagant arrangement, but in fact the advantages had been found completely to outweigh the slight additional bulk and complication apparently involved. One point was that initial input forces were enormously reduced below what was possible in a single stage ; a second point was that, by suitable selection of intermediate stage pressures and by limiting the gain per stage, manufacturing tolerances on many components could be relatively wide. In fact, no selective assembly or matching of valves had ever been necessary in any of the Admiralty-designed servos, large numbers of which had been made by mass production methods. Dynamically balanced valves, as referred to by Conway and Collinson in their paper, had their uses, but the necessity for these relatively expensive constructions disappeared when multi-stage working could be employed.

These same servos had a further property which might be of interest and which was not referred to in any of the papers. This concerned the arrangement of the feed-back link which cancelled the valve movement. If one looked at various figures in the paper by Hadekel and that by Conway and Collinson, one saw that this link consisted of a differential lever which restored the valve to its original position. In the Admiralty servos, however, the valve worked in a sliding sleeve and the feed-back link caused this sleeve to chase the valve. From the viewpoint of servo analysis, the two arrangements were identical, but from the standpoint of servo design when the highest sensitivity was sought, the completely altered distribution of inertias and friction forces made a profound difference to the performance obtainable ; the extra sliding piece with additional leakage was a very small price to pay for the advantage gained. It would, of course, be appreciated that the reference here was principally to servos in which the input force levels were very low—with hand-operated apparatus, for example, the differential lever was simple and completely effective.

This brought him to a point in the paper of Conway and Collinson which was not at all clear. When they said that they did not know how to make a small servo valve having an operating load under practical conditions as low as half a pound, did they mean this literally, because the Navy had for twenty-five years been using first-stage hydraulic servo valves of the dithered low-pressure type whose operating force in service was much less than a tenth of an ounce ? Many such valves were to be found in vital parts of the armament of H.M. ships during the last war, and he was not aware of any undue apprehension regarding their reliability, even under the difficult conditions associated with fighting ships in wartime.

Professor A. A. Tustin (Edgbaston) said that they might expect the mechanical engineers particularly to contribute to the better handling of non-linear problems in servo design. The electrical engineer was not so seriously troubled by non-linearities as the mechanical engineer, whose essential medium —the choking of the extreme of flow by valve —was a non-linear phenomenon. He wished to mention two points which he would regard as the present "cutting edge" of progress in the electrical field on servos. The first was a much more sophisticated view of what used to be called phase advance. "Phase advance" was a bad term. One had to modify the frequency response locus in such a way as to secure stability with accuracy, and that did not involve only phase advance ; it involved some particular combination of phase shift and attenuation which was suited to the particular purpose. Great advances had been made (perhaps to a good many people's surprise) in the reliability of the more complex networks which gave spectacularly better performance in this respect than the elementary condenser resistance networks and mutual inductances, and so on, which had been first used and which had been thought of as phase advances. He therefore suggested that from now on they should take a more sophisticated view of a suitable filter or modifying network and forget the term "phase advance," which was misleading. The other aspect in which he thought electrical engineers were making progress was in respect of the energy considerations in servos, where attempts were steadily being made to relate the optimum performance to the specification, taking account of the fact that the time constants depended upon the amount of power to be handed back. In electrical engineering that rule seemed very simple, because the simple time constants of the direct-current machine were proportional, certain design parameters being constant, to the power amplification for that machine. It was no good talking about mere voltage gain, and so on. If the time constants varied when one varied the size of the machine, then that must be put into relationship in order to obtain an overall optimum, properly taking account of the variation of time constants with size. They had heard of certain rules, such as that time constants depended mainly on the volume of oil consumed in the system and that this depended upon the product of displacement and the area which would be forced for a given power ; and he thought that similar rules to those could be obtained. He felt sure that attention ought to be given to these relationships between time constants and size so as to obtain a final overall optimum design.

Mr. J. E. M. Coombes (Manchester) said that several of the authors had emphasised the advantages of hydraulics and, while he would agree with them, he felt that care ought to be exercised. Where the quantity to be controlled was rotational it was true, as several of the authors had mentioned, that the torque to inertia ratios of hydraulic

motors were higher than those of electric motors. However, in practice that advantage was largely offset by the effects of compressibility of the oil; so that, generally speaking, there was not very much to choose between the hydraulic solution and the electrical one, at any rate in powers of, say, 5 h.p. to several hundred horsepower. That applied, he thought—again, generally speaking—as regards performance, size, weight, efficiency, and first cost. However, when one considered the control of motion in a straight line, there was no doubt whatever of the overwhelming advantages of hydraulic methods.

Mr. H. B. Sedgfield (Brentford) said that if one went to the full length of reducing the Bernoulli effects on a valve, one was still left with the frictional forces on that valve. In one of the papers there was the suggestion of using a taper in the downward stream direction of the oil which would centralise the valve and reduce friction. He remembered, however, a statement from the Vickers Company in America which had indicated that they had tried that sort of device, and that if one put in a taper of that nature there was a tendency for silting to increase. Even if one were successful in reducing the friction component on the valve, one was still left with any inevitable friction introduced by particles of oil. On this point he wished to make a strong plea. During the war he had seen the type of maintenance given to armament equipment in the Army. It was important to remember that, if one was considering armament equipment as opposed to civilian equipment, one could not rely on anything like the same perfection of maintenance in the field as one could institute in a manufacturing firm. In his own company considerable efforts had been made to have cleanliness in gyro manufacture, but in the case of the automatic pilot a rather different policy had been adopted. In experimental tests they had deliberately arranged for the oil system to be open to the atmosphere so that a certain amount of dirt could be collected. The servo had had to operate under those conditions of cleanliness, the idea being that if that could be achieved there would be some chance of satisfactory running in the field. He strongly supported Mr. Ford's comment that the double valve, with a pilot valve and a main valve, had proved extremely satisfactory.

Mr. J. Caldwell was interested in the application of servos to the governing of prime movers, and he thought it was a great pity that, since this was an Institution of Mechanical Engineers, there was not among the papers one dealing with velocity servos on governors. He recognised that there had recently been a very good paper on that aspect by Mr. Dennis, but he still felt that a further paper ought to have been included in the present group. There were, of course, certain reasons why there was no paper on velocity servo governors, one of them being that the velocity servo governor had developed over a very long period and had had considerable success in application. There had been no particular difficulty with it and consequently the prime mover engineers, having many other things to think about, they had perhaps not devoted as much attention to this subject recently as other engineers had done. Another reason had been indicated in the present papers. The governors were mostly controlled by a valve and (as various authors had indicated) the theory with a non-linear control by a valve was particularly difficult. Nevertheless, there was always room for improvement, and all prime mover designers were watching the developments in servo theory in the hope that some day there would be some results available to them which would enable them to improve their own system of governing. After studying the papers, he could only say that he was rather disappointed that the theory had not yet got to the point where it helped them very much.

Mr. H. Clausen (Bath) wished to put a point to Mr. Harpur. To what extent had the extremely elegant mathematical analysis of the hydraulic servo of the jack type been supported by trial? If it had been, he thought there was certainly something in it. There was also mention in the paper of the fact that pneumatic servos had not been developed to any great extent. Unfortunately, that was true, and it was a pity. The earliest precision servos used in fire control applications in the Navy had been pneumatic ones; the design date had been 1925, they had been fitted in H.M.S. "Nelson" and H.M.S. "Rodney" in 1927 and had been in use ever since then, and had only just gone out of fashion. The fact that they had gone out of fashion was due to Mr. Ford, who had also provided their successors. There was another point to which he had expected to see reference in the papers, but which was not mentioned. In the older days of servos the performance had always been reckoned as so many per second, which practically told one everything. For example, a machine which would give 10 deg. per second speed, with an accuracy of six minutes, was doing 100 steps per second. The number of steps per second which a servo could do was an almost overall criterion of performance. In none of the papers was there any reference to the number of steps per second which the servos described were capable of handling. As a quantitative figure it was extremely good. If a servo had fifty steps per second, it was so-and-so; if it had 200 steps per second, it was extremely good; and if it did 1000, then one wondered what had happened.

Mr. R. Westbury (Wolverhampton) said that in the paper by Harpur it was pointed out that the requirements of high stiffness and of stability were mutually opposed and that for a given aeroplane the right solution was largely a matter of compromise. He thought it might be of interest to review the various methods of obtaining high stiffness. The first was by using a high-response servo, i.e. a servo having a low value for

$$\frac{\text{Slope of flow—pressure drop curve}}{\text{Slope of flow—error curve}}.$$

A servo of this kind might be unstable either in itself or when combined with an aircraft input system. In order to achieve stability, resort might be made to error signal dampers or to velocity or acceleration feed-back systems. Secondly, low working pressures, i.e. large jacks, would give high stiffness. He was a little puzzled by Mr. Harpur's reference to the advantage of high pressures in this connection. It was true that the bulk modulus of the fluid increased up to about 1000 lb per square inch, but there was little increase to be had above that pressure, even with high degrees of aeration. Above 1000 lb per square inch working pressure the jack stiffness decreased in direct proportion to the area, i.e. inversely with the working pressure. He was speaking here, of course, of the mechanical stiffness of the fluid strut and not of its servo impedance. An analogy would seem to be in the use of low-strength structural materials where design was dictated by stiffness, not strength.

Thirdly, screw jacks would, of course, give a very high output stiffness, and this need not necessarily be obtained by mechanical inefficiency, i.e. irreversibility. If hydraulic motors were used to drive these screw jacks, adequate stiffness was obtained due to the small volume of oil subject to compression within the hydraulic motor. This volume was, of course, an extremely small proportion of the total swept volume for a complete stroke of the servo.

Comparing these methods, it seemed to him that the high-response servo, artificially stabilised, was functionally complicated and its reliability in remaining stable under aircraft service conditions was open to some doubt. The low-pressure servo was simple and should maintain its performance reliably, but it was rather heavy and bulky. The screw jack was mechanically complex, but functionally simple, and he thought that it undoubtedly offered the most reliable method of obtaining high stiffness. It would be interesting to have other views on this comparison.

Regarding the theoretical treatment of servo mechanisms, it would seem that the stiffness and stability combined with the output elasticity and inertia were fairly accurately predictable. However, the factors influencing the stability of the complete installation, including the input system—i.e. the various structural distortion and inertia feed-backs—were much more difficult to treat. It might well be that not until the aeroplane was built was there sufficient information available to make a complete assessment. This question of undesired feed-backs was often, in his experience, the determining factor in power flying control design, and the carefully calculated characteristics of the servo might well require drastic modification when it was finally installed.

Mr. F. B. Levetus (Coventry), referring to the paper by Conway and Collinson, felt that considerable help in distinguishing between frictional and Bernoulli forces could be obtained by measuring the total forces under normal conditions and by measuring them in addition under the same conditions, but with a rotating piston and with a particularly careful equation. The question of dither had been frequently mentioned and its value for removing friction silting on hydraulic parts had been stressed. But he thought that perhaps sufficient had not been said about the freeing and maintaining of a proper lubrication film on all other links in the chain, as well as on the question of averaging backlash where this inevitably occurred.

Mr. F. H. Towler, referring to the paper by Conway and Collinson, in which there was mention of the possibilities of employing higher pressure, said that he was very much in sympathy with the use of higher pressure, but the great enemy was compressibility. At low pressure, apparently, there was compressibility due to aeration of the oil; there was compression of the bubbles of the oil. As the oil pressure increased above a certain figure at higher pressure the air went into solution, and therefore at higher pressure one was simply concerned with the bulk modulus of the oil. But the result was more or less the same. There was considerable compressibility at low pressure and considerable compressibility at high pressure. The ultimate result was that there was energy stored between the control valve and the motor. Even with a motor like the one illustrated in the paper by Harpur there was still stored energy. There was still the question of compressibility. Whether there was compression on both sides of the piston or not, there was still the same problem to be faced. It was this fact which probably accounted for the fact that pneumatic servos were not used very much. He was rather surprised that there had been very little mention of noise.

All those who made pumps knew that almost always as the pressure was increased the noise increased.

Mr. J. O. N. Lawrence, referring to the method of impedance testing described by Mr. Watson, asked the author whether the technique was to be used in a quantitative sense or purely as a qualitative action. There was no question about the value of the technique qualitatively, but he would regard it rather as a tool which provoked thought and helped one to look at that part of the system which required attention rather than as something which did anything practical about it directly. The alternative approach which he had seen in action in some places was to use an automatic calculating machine and feed in mounds of data and then get an answer. But the value of the answer obviously depended on the accuracy of the initial data.

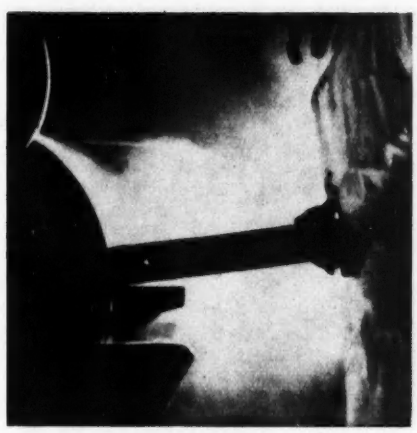
Mr. W. G. Lisle (Hayes, Middlesex) said that his own experience with the analysis of the valve type system showed that in the absence of mathematical solutions of high order non-linear differential equations, accurate prediction of practical servo behaviour was not possible. The assumptions and simplification necessary to utilise known mathematical methods gave results which were too wide of the mark to be of much use to the engineer. The most complex aspect of servo mechanism design, particularly when related to elastic environments, was that of stability. The authors of the relevant papers had listed the generally accepted critical parameters, but here again the development engineer sometimes found contradiction and confusion. One of the most acute practical difficulties confronting the investigators of aircraft servos was that of satisfactorily simulating, on the test bench, many of the critical parameters, such as stiffnesses, parasitic forces and backlash. So much so that, as was fairly well known, it was necessary at present to operate the servo in its actual aircraft environment in order to ensure complete freedom from instability. From all aspects it would appear that they were suffering in general from insufficient information to bridge the gap between the limited existing theory and practice, and that there was a very pressing need for extensive theoretical laboratory and field work in order to establish really reliable design criteria. He also felt that more should be known regarding the combined or interacting effects of servo instability and control surface flutter and that the present ruling of endeavouring to ensure well-displaced natural frequencies rather over-simplified the problem.

Mr. C. B. V. Neilson said that his remarks related to the paper by Conway and Collinson and concerned the question of terminology. To those whose connection with problems of servo mechanisms concerned their overall behaviour rather than their detailed design, this question of terminology was of primary importance in a subject where there was still considerable ignorance, and for this reason he thought that this section of the paper was particularly welcome. It would have been of even more value if the definitions could have been more precise. The electrical communications engineer was able to define his amplifiers precisely by means of their frequency/gain characteristic, their input and output impedances, their stability characteristics and their power handling capacity. When designing a complete transmission system he could examine these curves and select an amplifier to meet his requirements or design one accordingly. The problems of the servo engineer were similar, but there still appeared to be no widely understood language in which he could specify the characteristics of his equipment in such a way that it would be clearly defined. It seemed to him that this stage must be reached before the servo art could be regarded as being reasonably adult. These remarks applied particularly to applications in the aircraft field.

The authors made short replies and the conference ended.

Dust Suppression on Grinding Machines

As a result of investigations carried out at the Dust Research Station of the Research and Development Section of the British Steel Founders' Association, effective means have now been developed for suppressing to a considerable extent the dust discharged to the atmosphere when grinding is done on the stand or pedestal grinding machines such as are used in foundries. The Association has issued particulars of these dust suppression means which are stated to apply equally well to machines having wheels with peripheral speeds from 9000ft to 5400ft per minute. The means evolved can be fitted to existing machines or new equipment, and their effectiveness can be seen from the two photographs reproduced on this page, where a piece of wood is being ground on a standard machine and a machine incorporating the improvements.



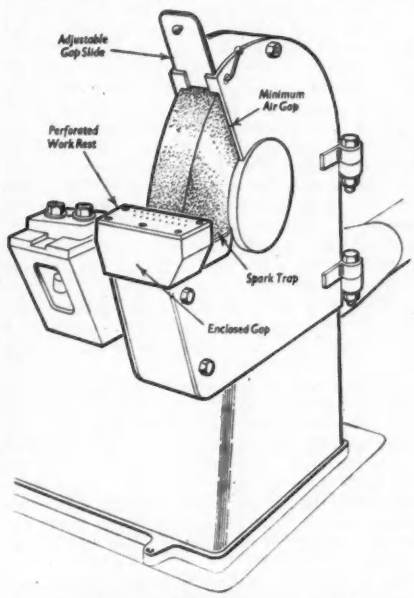
Dust Emission from a Normal Machine

For the preliminary observations in these investigations at the dust research station, "Perspex" end covers were fitted to standard 24in grinding units, and by this means it was possible to observe, under appropriate conditions of illumination, the flow of dust-laden air inside the machine cowling. These observations revealed that air streams being drawn into machines of conventional design prevented dispersion within the cowling of the stream of dust-laden air produced by the grinding operation and caused it to adhere to and rotate with the periphery of the grinding wheel instead of being extracted through the exit duct to the dust collector and fan system. The dust stream adhering closely to the wheel emerged from the cowling in front of the operator and was subsequently deflected by the work rest and by the work itself directly into the breathing zone of the operator.

Dust Emission from a Modified Machine

By controlling the ingress of air being drawn into the cowling by the extraction system, and by concentrating the effects of extraction solely upon the dust stream, it was found possible to reduce very substantially the amount of dust-laden air rotating with the wheel. For this purpose a work rest was designed to make the extraction system effective directly on the underside of the rest itself, by extracting the dust as near to the source of generation as possible.

Further modifications included reducing to a minimum the gap between the casing and the sides or flanks of the grinding wheel, and the fitting of an easily adjustable gap closing slide at the point where the wheel emerged from the cowling immediately in front of the operator's face. As wheel wear takes place the slide can be adjusted to reduce the gap. The work rest was also altered to embody either slots or perforations. This modification, together with the suction applied below the work rest, prevents the work rest from acting as a stripping means and deflecting the dust stream towards the operator before it enters the cowling.



Grinding Wheel with Improved Hood

The recommendations made as a result of the investigations are shown diagrammatically in the drawing on this page. It is pointed out that the modifications have been made in such a way that the control of the dust has been brought as near as possible to the dust origin, the dust stream has been confined within the cowling itself, and they do not involve any complicated innovations or alterations to the construction of stand grinding equipment.

GUIDE TO BIRMINGHAM.—The City of Birmingham information department has produced an illustrated brochure, entitled "Guide to Birmingham, 1953." This brochure, which costs 1s., gives details concerning the history, industries and social and civic affairs of Birmingham, and contains a map of the Birmingham area and a detailed street plan of the city centre.

SURVEY OF BUILDING IN SANDSTONE IN SCOTLAND.—The National Building Studies Special Report No. 20, published by the D.S.I.R., describes the results of a survey made during 1949–50 to discover the comparative costs of building in Scottish stone and in alternative materials, and to suggest economies in the winning, working and building of the stone. It was found that for every type of building the cost of construction in stone was high. It is unlikely that it can be reduced to the point where it could compete with brick and concrete construction costs, it is pointed out, although changes in the technique of stone dressing and building could bring about savings. The reduction of costs would necessitate the concentration of the quarrying industry and the increasing of the output from those quarries remaining in production.

Operating Experiences with Two Gas Turbine Locomotives*

By A. W. J. DYMOND, B.Sc., M.I.C.E., M.I.Mech.E.

No. I

THE purpose of this paper is briefly to refer to some of the problems which emerged in the design of the two locomotives of this kind for this country, and to give some details of the experience so far gained with the engines since they were put into service.

At the outset the case for the gas turbine locomotive can be briefly stated. It offers greater power-weight-space ratios than any other prime mover for railway use. It has an optimum thermal efficiency nearly two and a half times that of a normal steam locomotive, but not yet approaching that of the diesel. It can burn residual fuels and may well in the not-too-distant future prove to be able to burn coal. In common with diesels and straight electric locomotives it requires very little servicing between trips and has a very high user potential. Owing to the small number of moving parts gas turbine locomotives are also claimed to require substantially less in maintenance than diesel locomotives, as well as having very reduced consumption of lubricating oil.

On the debit side gas turbines have not as yet achieved thermal efficiencies approaching diesel figures, while the part-load efficiency falls off substantially compared with the optimum. Since a considerable proportion of the operating time of a locomotive is occupied at much less than maximum power, the effect of these two factors together is to give a useful-work-to-fuel ratio for a complete trip not very different from that of a good steam locomotive. What may be termed an ancillary difficulty is one which arises with all non-steam locomotives, i.e. the necessity to provide steam for train heating. Entailing, as it does, the provision of a special boiler, and the carrying of a water supply on the engine solely for the purpose, this requirement constitutes a regrettable complication in the design of the locomotive.

Other factors having adverse implications compared with steam locomotives are the noise of the compressor, the smell of the exhaust fumes and their effect on the fabric of tunnels and other over-structures. These factors loom large in the minds of those contemplating gas turbine locomotives in the abstract. The practical experience gained with the two referred to in this paper will be the subject of comment in the appropriate context.

Two features of gas turbines having pronounced effects in more extreme climates have no significance in this country, viz., the complete independence of water supplies (except so far as necessary for train heating) and the substantial difference in output caused by wide variations in the ambient temperature.

With the exception of one French design, the only gas turbine locomotives which are, or have been, in service anywhere have all incorporated electrical transmission between turbine shaft and road wheels. This electrical transmission brings in its train the necessity for control devices similar to those used on large powered diesel-electric locomotives. The control mechanism has to perform a sort of juggling turn with the fuelling rate, the turbine speed and the main generator excitation as the three balls concerned. While the principles of such controls are not peculiar to the gas turbine, the incorporation and adaptation of these for gas turbines does add complications, and additional possibility of breakdown to the gas turbine *per se*. The potential gain to the gas turbine offered by the successful development of a mechanical drive for a locomotive is very evident.

Descriptions of both locomotives have been published in detail in the technical press.

Any account of the experience which has been obtained with these two locomotives in the Western Region should start with chronological stories of their doings since first delivered. It will then be in order to enlarge as far as may be desirable on some of the outstanding incidents. From the sum of this experience, together with the results of special trials with and without dynamometer car, some opinions can be expressed—very tentatively—on the merits of the claims made on behalf of gas turbine locomotives.

At the outset it is to be strongly emphasised that no attempt will be made, and no comment implied or expressed, to compare the two locomotives with each other. So far as facts lead to obvious conclusions, they will speak for themselves. Another comment which should be made in this context is that at the time of writing the Swiss locomotive has been in service during nearly three years and has completed 122,000 miles, whereas the Metropolitan-Vickers locomotive has been in service nearly one year and has run 42,000 miles and neither has yet had any general overhaul.

THE BROWN-BOVERI LOCOMOTIVE NO. 18000

The Brown-Boveri locomotive, after having had a few runs in Switzerland, was shipped to this country via the Zeebrugge-Harwich train ferry and was towed to Swindon, where it arrived on February 5, 1950. It first ran under its own power on British metals on February 13th, a light engine trip from Swindon to Badminton and back.

From this date until May 19, 1950, when the locomotive hauled its first loaded passenger train (2.15 p.m. Paddington to Swindon) many trips were run for the dual purposes of adjusting

Fig. 1—Typical Defective Combustion Chamber Liner

controls, &c., and training of staff. During this period and subsequently up to September, 1950, a Swiss engineer from Brown-Boveri's works at Baden was permanently on the locomotive, and his services were supplemented as required by one or more additional of the firm's engineers. The period of initial adjustment and training of staff, which was likely to be lengthy in any case owing to the novelty of the locomotive, was unfortunately extended by some weeks owing to a failure of the blading of the compressor on March 9, 1950, when hauling a train of empty stock between Swindon and Bristol. The failure, which consisted of the shedding of the first three rows of blades in the compressor was adjudged to be due to "flutter," caused by some differences, as compared with the Swiss Federal locomotive, in the nature of the flow of the ingoing air, due to the incorporation at the intake of water jet nozzles provided for blade cleaning.

The new blading fitted during the repair was equipped with damping rings, and since that date the compressor has given completely trouble-free service. After about a week's service on passenger trains between Paddington and Swindon, following the initial run on May 9, 1950, the locomotive went into service between Paddington and Plymouth on May 22nd. It continued in this service until June 14th, taking the 3.30 p.m. from Paddington on one day, returning with the 7.15 a.m. from Plymouth on the following day. This period was interrupted for four days at the beginning of June while a temporary lining for the combustion chamber was replaced. Subsequently it has been the experience that these liners have needed frequent changing, and a further comment will be made when summing up the whole experience to date.

On Monday, June 12, 1950, a series of trials were arranged to ascertain the maximum trailing load that could be safely hauled up the gradient from Plymouth to Hemerdon in South Devon. It was assumed at that time that this should be fixed at the maximum load that could be restarted on the steepest part of the bank (i.e. a 1 in 42 rising gradient) and hauled to the top without overheating the electrical machines. The trials were rather disappointing in some ways and the locomotive failed to restart with 350 tons gross trailing load, although on a previous occasion 290 tons had been restarted. A successful run was made without stopping with a load of 400 tons, the speed falling to 10 m.p.h. at the summit after entering the gradient at about 50 m.p.h. The generator and the traction motors were examined on reaching Hemerdon and there was no evidence of excessive heating.

It was therefore a sad blow when the locomotive failed while hauling a passenger train on June 13th due to a serious defect in No. 2 traction motor.

This eventually proved to have been due to a loose binding coil threshing around among the brushes, completely wrecking these and the ends of the field coils on the stator, and subsequently being caught between the armature and the pole pieces and being reeled right through the machine. Despite considerable damage to the windings, however, no sign of overheating was apparent, all the damage being entirely mechanical due to the loose binding wire. The defective motor was removed for repair and the locomotive put into service temporarily with three motors.

In this state a demonstration run took place from Paddington to Westbury via Newbury, returning via Swindon. Following this the engine did a few days' duty with passenger trains between Paddington and Swindon, at the end of which it was withdrawn for the repaired traction motor to be installed. At this date (July 15, 1950) the locomotive had some 8500 miles to its credit. After its restoration to service, still on the Swindon run, it ran without further interruption until towards the end of August and in the last week of that month was restored to the Plymouth service, doing the round trip in two days as before. This continued until the end of October; it was then necessary to withdraw the engine for work on the train heating boiler. This work unfortunately precluded further service from the locomotive until the end of January, with the exception of a few days on the Paddington-Plymouth service early in December.

This practically rounded out the first year's work after delivery. The locomotive had covered 23,200 miles and the turbine had given 530 hours. During this period, apart from the major incidents referred to, there were various stoppages due to smaller defects, such as leaking roof tank, broken details in thermostats, oil pump bearing overheated, as well as a number of minor electrical defects, such as blown fuses, bad contacts, &c.

Ignoring the heavy stoppages due to the traction motor failure and the difficulties with the train heating boiler, the only serious items concerning the gas turbine as such were the compressor blading failure and the frequent necessity to change the combustion chamber liner.

During the second year's working the only serious stoppage was a disastrous fire which broke out in the heat exchanger, completely wrecking the whole unit (Fig. 3). This was deemed to be due to heavy accumulations of soot in the interior of the tube nest, which were ignited by a short period of high-temperature running followed by a lay-by period. A new heat exchanger was quickly built in Switzerland and fitted to the locomotive immediately on its receipt in this country. In order to minimise future risk of such fires, the access doors to the interior of the heat exchanger were increased in size to permit more perfect washing out of the interior. The combustion chamber lining had to be changed on a number of occasions, being replaced as convenient by repaired liners or by new spares. Other minor troubles also occurred to the light fuel tank, the diesel engine radiator, some of the thermostats, and the heavy fuel oil pressure system. None of these troubles were of any great magnitude, but days were lost to traffic due to some of them.

During this year until the end of April the

* Paper before Institution of Locomotive Engineers, February 18, 1953. Abstracts.

engine was kept on short runs between Paddington and Swindon. From the beginning of May it worked a daily trip from Paddington to Bristol and back and this was supplemented at the end of the month by an additional daily trip to Swindon and back, the weekly mileage then reaching just over 2200 miles. The heat exchanger fire put it out of service until the middle of August, when it again took up the 2200 miles' weekly schedule between Paddington and Bristol and Swindon. It was then put on a series of runs between Paddington and Plymouth for dynamometer car testing. These trials have been fully reported in the technical press† and further comments on these tests will follow in this paper. The engine continued on the Paddington-Bristol-Swindon schedule throughout the remainder of the second year of its operation and had completed 72,590 miles up to February 2, 1952. The turbine hours to that date aggregated 1913 hours. Throughout the third year of running to the time of writing the engine continued on the same schedule. It had to be withdrawn from traffic, however, in mid-September owing to slight cracking being observed in the first and second rows of blades of the turbine stator. These cracks, of which there were two or three on a blade (Fig. 2) extended from the trailing edge across the width of the blade by amounts varying up to half the width. Immediate arrangements were made by the builders to manufacture and despatch replacements, and at the time of writing the engine was in the shops for the reblading to be carried out. The cause of this cracking was attributed, at the time of writing, either to bad temperature distribution at the turbine inlet due probably to an excessively long flame or to delayed ignition. The blades exhibited no evidence of scaling. As the enforced stoppage caused by this defect coincided very nearly with the programmed date for the installation of a larger train heating boiler, opportunity was taken to do this at the same time. Some attention was also given to re-turning of the tyre profiles, although these were by no means then urgently in need of such work. The mileage at the date of the stoppage was 122,118 and the total turbine hours had reached 3296 hours.

General Comments on the Behaviour of the Brown-Boveri Locomotive

(a) *Maintenance.*—As will have been seen, there have been three major incidents since the locomotive went into service : the compressor failure, the traction motor failure, and the heat exchanger fire. Each of these has been very efficiently repaired by the firm and the component has given no further trouble. The most persistent trouble has been, as stated, the short life of the combustion chamber lining. In all seven linings have been made and fitted to the combustion chamber. The first and second were of ¼in thick alloy steel (25 per cent chromium, 20 per cent nickel), and gave only a single life each, one of 215 hours and the other of 100 hours. Subsequently liners were manufactured of thicker material (20 per cent chromium with titanium), the latest ⅜in thick, and most of these have given additional service after repair. One aggregated over 1000 hours in four lives and another 980 hours in three lives. The distortion and wasting which has characterised this liner deterioration (Fig. 1) has pointed consistently to the difficulty of ensuring satisfactory combustion of residual fuel over the entire range of operation.

There have been, of course, a number of less serious items which have necessitated short stoppages or work at weekends during normal servicing. None of these has been persistent and none has caused more than normal work in its correction.

The locomotive has been stabled throughout the period at Old Oak Common and has had servicing each Sunday. This includes washing out compressor and heat exchanger at approximately 600 hours and 200 hours respectively. The washout is carried out with a detergent solution in the compressor and plain water in the heat exchanger. The normal weekly attention comprises replenishing lubricants, brake adjustments, exhauster compressor examination, attention to diesel engine and the like, as well as visual inspection of compressor blading and heat exchanger tubes when these items are not washed out. Similar attention is given to electrical items, including topping up battery, replenishment of oil lubricated bearings on traction motor armature and gears and inspection of safety and telltale devices.

(b) *Operation and Utilisation.*—It will have been very noticeable from the chronological account that the locomotive has spent comparatively little time on the Paddington-Plymouth route for which it was primarily intended. The reason for this is threefold : in the first place the emphasis in the traction motor design has been on speed and not tractive effort ; consequently the capacity of the locomotive to deal with the heaviest trains over the steep gradients in South Devon has been somewhat restricted.

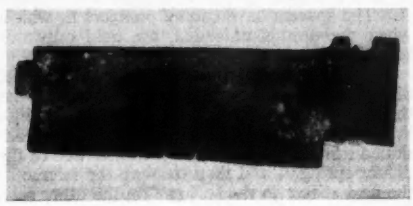


Fig. 2—Typical Defective Turbine Blade

The inconclusive trials held in June, 1950, followed by the traction motor trouble delayed any decision as to the safe load for these gradients until a thermal indicator could be fitted to indicate the temperature rise in the generator and traction motors and until further trials could be arranged. These trials took place in May, 1952, and as a result it was decided that a "King" load could be hauled with safety provided no stop were made on the gradient. What, in the second place, has an important impact on the use of the engine on any services is the necessity for an adequate link of trained staff—not too large—who would be likely to lose touch with details between driving turns on the engine, and not so small, as to restricts flexibility in the use of the locomotive to the few people trained to handle it. This aspect, allied to the early inadequacies of the train heating boiler, constituted the other main restriction on the use of the engine to Plymouth. Since the boiler was insufficient to maintain twelve-coach trains in good heat for the five hours necessitated by the Plymouth run the engine was restricted to the Bristol run, where trains of twelve coaches could be maintained in reasonably good heat for the relatively short run. When the summer season released the engine from the restriction due to the boiler the fact that trained staff were in links appropriate to the Bristol route precluded using the engine on the Plymouth route except by special arrangement.

Fig. 3—Fire Damage to Heat Exchanger

(c) *Fuels and Fuelling.*—As has been stated, the locomotive uses two fuels, gas oil for starting the turbine, running the diesel engine and firing the train heating boiler, and a fairly heavy residual fuel (950 seconds Redwood No. 1 at 100 per cent F.) for normal running of the gas turbine. Fuelling points with both fuels available were in existence at certain depots of the Western Region. The existence of these facilities at certain depots —and their absence at others—has obviously a bearing on the points between which the locomotive can operate without refuelling. The gas oil offers no serious problem, but the residual oil—requiring, as it does, heating in winter—entails handling facilities with heating coils in the tanks and steam tracer pipes on the oil lines. In this sense the use of a residual fuel of high viscosity is a disadvantage from an operating point of view, as fairly costly facilities must be established at every motive power depot at which the locomotive is scheduled to refuel. The motive power depots at Old Oak Common (London), Swindon and Laira (Plymouth) are fully equipped to deal with both oils, but no other depot on the Western Region now has facilities for dealing with heavy oil. Hence services are necessarily confined to out-and-home trips without refuelling or trips between the three depots mentioned.

The fuel consumption has remained remarkably constant throughout. In the first twelve months including, as it did, the initial trials and consequently excessive light engine miles, the average was 3·03 gallons per mile. In the second twelve months the figure was also 3·03 gallons per mile, while up to time of writing in the third twelve months it has registered 2·81 gallons per mile. The only critical reading of fuel consumption arises from the series of dynamometer car tests carried out between Paddington and Plymouth in September, 1951, the results of which have been published. In this the corresponding figure of oil fuel consumed varies from 23·02 lb per mile to 28·3 lb per mile. With the specific gravity of the oil at 0·94 (average) at normal temperatures this is from 2·47 to 3·00 gallons per mile. As these values are substantially of the same order as the annual figures, it is reasonable to assume that the ratio of oil per d.b.h.p.-hour (1·93 lb to 2·17 lb) obtained on the tests obtains throughout the operating period. This is the equivalent of an overall work-to-fuel ratio of about 6·7 per cent. Compared with the optimum efficiency at full load of about 16·8 per cent obtained on the bench tests of the power unit at Baden, this is perhaps surprising. The explanation lies in the average power required of a locomotive being in the vicinity of 50 per cent or less of full power, combined with the strongly drooping characteristic of the efficiency curve for the gas turbine. In this connection idling and light engine running account for far more than their due share of fuel consumption.

It is, however, interesting to relate the fuel consumption per mile to an equivalent coal basis and compare this with normal steam locomotive figures. Taking a gross calorific value for the oil at 18,630 B.Th.U. per pound, with an average specific gravity of 0·882 at 220 deg. Fah. (i.e. temperature at burner), the equivalent coal at 14,000 B.Th.U. per pound works out at 35·6 lb per mile. This is a very favourable figure compared with a general figure of 50–55 lb of coal per mile for all coal supplied to steam locomotives using varying grades of coal, the average calorific value of which would almost certainly be less than 14,000 B.Th.U. per pound. The difference between the low equivalent coal (35·6 lb) and the general figure quoted (50–55 lb) is also in part explained by the elimination of standby and lighting-up losses, as well as by the effect of the wider variety of operating conditions in general service, which have adverse reactions on fuel figures for all steam locomotives compared with those for the gas turbine on its limited and selected duties.

(d) *Lubrication.*—Gas turbine locomotives are claimed to have very low figures for lubricating oil consumption, and in this connection the following record of the behaviour of the Brown-Boveri locomotive will be of interest. For a weekly service involving 1750 miles and approxi-

† The Engineer, May 16, 1952, page 665, &c.

mately fifty hours' running the following quantities were used per week for topping up :—

Diesel engine sump	1½ gallons
Compressor exhauster	1 gallon
Traction motor gears	1 gallon
Traction motor armature bearings ...	2 pints
Various grease points...	4½ lb

Every three months' service the main lubricant tank of the turbine required 10 gallons for topping up, while the sump of the diesel engine and exhauster compressor in the same time have required some 20–22 gallons for complete changing of the oils in the sumps at the prescribed intervals.

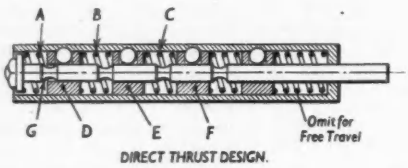
Over the period from the commencement in service the consumpton of lubricating oils (as distinct from greases) has averaged between 2·5 and 2·8 pints per 100 miles.

(To be continued)

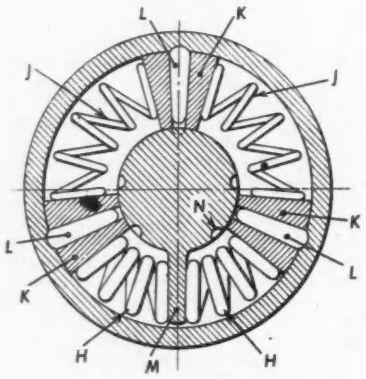
A "Reversed Force" Spring

PARTICULARS of an interesting new form of spring known as the Fisher "reversed force" spring have been received from Approved Inventions, Ltd., 7, Princes Street, London, W.1. This spring, unlike the normal coil spring, which exerts its least resisting force at the beginning of compression, exerts its greatest resistance at this stage, and can be arranged so that the resistance offered thereafter diminishes or is kept relatively constant.

The reversed force spring is essentially a simple arrangement of two or more coil springs built into a composite unit, and its design can clearly



DIRECT THRUST DESIGN.



ROTATIONAL DESIGN.

Arrangement of Reversed Action Springs

be seen in the diagrams we reproduce above. One diagram shows a spring arranged for direct thrust and the other diagram a spring arranged for rotational operation.

Referring to the direct thrust diagram, it will be seen that a number of separate springs *A*, *B*, *C* . . . is mounted in a body and separated by spacer blocks *D*, *E*, *F* . . . The spring *A* is the strongest in the unit, and the springs, *B*, *C*, &c., are progressively weaker. Each of the spacers is locked in position, whilst the spring is extended by a ball which locates in a groove in the body and is held up by a central spindle. When a load is applied to the spindle to draw it to the right, the load is first imparted to the heavy spring *A*, which is confined between the spindle head and the spacer *D*. As the load increases, the continued movement of the spindle along the body brings the groove *G* in the spindle into line with the bore containing the ball in the spacer *D*. The ball drops down into the spindle groove, and the spacer *D*, with the fully compressed spring *A* locked to it, then moves with the spindle to transfer the load to the lighter spring *B*. As the load increases and the spindle movement continues, successive spacer locking balls are released and progressively weaker springs come into effect. On the load on the spindle being released, the action is reversed and the kinetic energy stored in the springs is released as each successive spacer is restored to its locked position. This imparts a constant or, according to the springs fitted, increasingly greater return load on the spindle until it reaches its maximum extension with the release of the spring *A*. If free travel is required at the end of the spring compression the final spring at the rear of the body can be omitted.

In the rotational design, it will be seen that in the annular space between the case and the central member of the unit, there are two heavy springs *H*, and two light springs *J*, separated by spacers *K*. The spacers have sliding plungers *L*, which, when the unit is unloaded, are held outwards to register in grooves in the case.

When the central member is turned in one direction or the other, its arm *M* first compresses the heavy spring *H* until the groove *N* comes into line with the holding plunger in *K*. With continued turning the load is then transmitted to the lighter spring *J*, and then through the release of the next spacer to the spring *J* on the other side. When the load is released, as in the previous instance, the energy stored in the springs is progressively released to give a light return load followed by a heavy load. A rotational unit of this design could be used for closing swing doors. In such a case, the greatest effort is desirable at the end of the movement to keep the door closed, but the main resisting force required during opening relatively weak.

When the door is fully opened with the springs compressed, the final plunger registers in a groove to hold the door in that position. Upon a light closing load being imparted to the door, the plunger is released and the springs come into effect to close the door.

A Flash Lamp for Use in Ophthalmology

A HIGH-INTENSITY flash lamp, which enables colour photographs to be taken of the retina of the eye, has been developed by the British Thomson-Houston Company, Ltd., with the co-operation of the medical illustration department of the Institute of Ophthalmology. The new lamp, which is shown in the accompanying illustration, is designed to give the necessary short exposure to eliminate the effect of uncontrollable eye movements and to provide the intense level of illumination required for colour photography. We learn that lamps of this design, known as the "Mazda" FA.5 flash tube, are being used by Dr. Hansell, of the Institute of Ophthalmology for establishing colour photography as a routine part of the diagnosis and treatment of eye complaints.

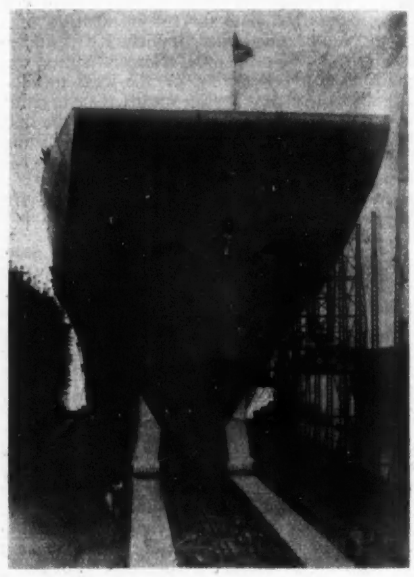
The flash tube is a hard glass cylinder of 110mm overall length, with an electrode sealed into each end to form an arc gap of only a few millimetres. It is filled with zenon at a pressure of about 1 atmosphere, and the light source is 4mm to 5mm long and 2·5mm wide, with a maximum brightness of 6000 Candelas, when operating continuously at 150W.

When used intermittently the flash intensity is about 1,000,000 Candelas for a one-twenty-fifth second duration. The rate of flash at maximum dissipation is one flash per ten seconds, and the tube has a life of 5000 flashes. The maximum and minimum values of the operating voltage are 2000V and 1000V respectively ; the anode/cathode breakdown voltage is 2500V (initial) and the approximate trigger voltage is 10kV.

Flash Tube for Colour Photography in Ophthalmology

Launch of H.M.S. "Hermes"

ON Monday, February 16th, the aircraft carrier H.M.S. "Hermes" was launched from the Barrow yard of Vickers-Armstrongs, Ltd., the naming ceremony being carried out by Mrs. Winston Churchill, following a short religious service conducted by the Bishop of Carlisle. The ship is the tenth to bear the name and is the second to be built as an aircraft carrier. Her predecessor was the first ship of the Royal Navy to be specially designed as an aircraft carrier and was built at the Naval Yard by Sir W. G. Armstrong-Whitworth and Co., Ltd., and launched in 1919. She was towed to Devonport for completion and joined the Fleet in 1923. Her main particulars were : length overall, 598ft by 90ft width over the flight deck, and a displacement of 10,850 tons. A complement of fifteen



H.M. Aircraft Carrier "Hermes"

aircraft was carried and the ship was propelled at 25 knots by two sets of geared turbines developing 40,000 s.h.p. The ship saw service during the second world war and was sunk off Ceylon by Japanese aircraft in 1942. Two survivors, Captain Creed and Commander Black, were present at the launching ceremony of the new "Hermes." This latest aircraft carrier is one of eight enlarged light Fleet carriers which were ordered towards the end of the war; four were subsequently cancelled, and work on the remaining ships was practically stopped. The "Hermes" gives her name to this class of aircraft carriers and is the last of the four to be launched, the others, the "Albion," "Bulwark" and "Centaur," being already afloat. As laid down in 1944, the principal dimensions of the ship are : length overall, 741ft 6in ; length between perpendiculars, 650ft ; extreme beam, 90ft, and a displacement of 18,300 tons, the maximum draught being 26ft 6in. Vickers-Armstrongs is also building the main machinery which consists of a twin-screw arrangement of Parsons geared turbines, taking steam from Admiralty pattern

three-drum boilers, and believed to be capable of developing about 75,000 s.h.p., sufficient to give the ship a speed approaching 30 knots. The anti-aircraft armament will include a large number of 40mm Bofors weapons and the number of aircraft to be carried is variously estimated at between forty-five and sixty, but this will depend upon the developments in aircraft design and the operational functions of the aircraft allocated to the ship. While work on the class has been virtually at a standstill, opportunity has been taken to modify the design of the ship to incorporate the experience gained during the war and also devices of more recent date. In particular, the steam catapult, the prototype of which was demonstrated successfully when fitted to H.M.S. "Perseus," will be included in the ship's equipment, and adjustments will be made to the flight deck arrangements to embody the angled deck. This concept has been devised to eliminate the need for a crash barrier and enable an aircraft to take off again should the arrester gear fail. Another innovation is the introduction of an additional aircraft lift at the ship's side. The ship's complement, numbering approximately 1400 officers and ratings, will have comfortable quarters and bunks are to be fitted instead of hammocks, while illumination of the living spaces will be effected by fluorescent lighting.

The Short "S.B./5." Adjustable Swept Wing Research Aircraft

THE Short "S.B./5"—the "adjustable wing" research aircraft which first flew last December—has now completed a considerable number of flights, and some further details of the aircraft and research programme have been released. Its main task is to investigate problems which arise in the handling of swept-back wing high-speed aircraft. As is generally recognised, difficulties are encountered in maintaining full and immediate control of swept wing aircraft at low speeds owing to a tendency for the air flow to break away or "spill" in the region of the wing tips, thus causing loss of stability and a tendency for the controls to appear not to respond at critical speeds, such as taking off or landing. The results of the present investigations are to be made available to the whole of the aircraft industry.

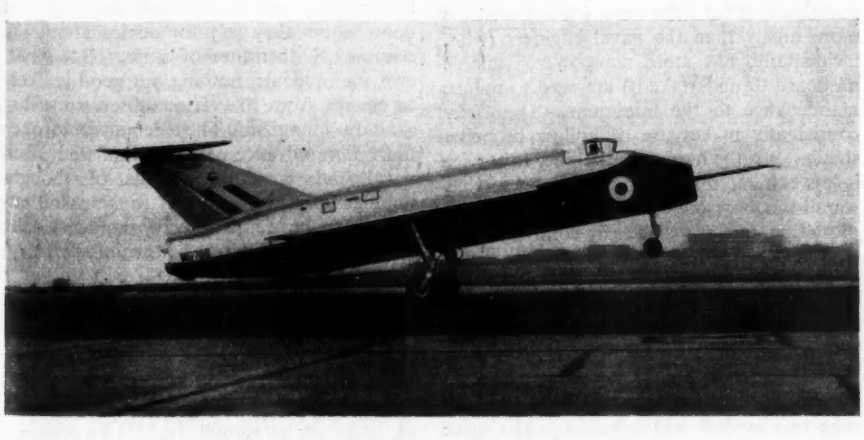
The "S.B./5" was designed so that varying degrees of sweep-back can be applied to the wings. The tailplane, which has a delta configuration, can also be positioned either at the extreme top of the fin or below the rear part of the fuselage and its angle of incidence is variable.

A programme of test flying to investigate the low-speed handling characteristics of all the combinations available is to be carried out.

The varying degrees of sweep-back angle are achieved by fitting alternative components and four following configurations can be tested; angles of 50 deg., 60 deg. and 69 deg. with the high tail unit and an angle of 60 deg. with a low tail unit. So far all flying has been carried out with a sweep-back of 50 deg. The wings show little taper and have tips cut square to the longitudinal axes of the machine. The wing span ranges from approximately 26ft to 35ft. The angle of incidence of the tailplane can be varied in flight and set to any desired angle between ±10 deg. Full-span leading edge flaps are fitted and the wings are all metal structure with plywood covering the leading and trailing edges.

The undercarriage is non-retractable, the bottom of the main legs being located by a radius rod. The main legs appear similar to a recently announced Messier oleo-pneumatic unit, embodying a levered suspension principle. The attitude of the legs can be changed to enable each wing configuration to be tested at various centre of gravity positions.

A Rolls-Royce "Derwent" engine is situated well aft of the pilot. Anti-spin and braking parachutes are fitted and our illustration shows the landing attitude of the aircraft prior to the release of the braking parachutes. The steep slope of the nose of the machine can be seen to improve the pilot's view during this phase of the landing. The overall length of the "S.B./5" is 47ft 4in and its height to the top of the fin approximately 16ft 7in.



A Characteristic Landing Attitude of the "S.B./5"

Cooling of Aggregate for Vaitarna Dam

(By Our Indian Correspondent)

THE Vaitarna dam, which is under construction as part of a water supply scheme for the City of Bombay has already been described in these columns (THE ENGINEER, October 31 and November 7, 1952). Some further details are given here, however, of the cooling of the aggregates at the dam site, which is being tried out for the first time in India. The Vaitarna dam is a gravity structure across the Vaitarna River, 1820ft long by 269ft high in the deepest part. Its estimated cost is about Rs. 7·15 crores (£5·36 million). The total quantity of concrete required for the dam will be approximately 700,000 cubic yards. The basic concrete material is basalt rock obtained from nearby quarries, where crushing and screening of both coarse and fine aggregates is carried out. From the bins of the crushing plant, various sizes of both fine and coarse aggregate are carried by a 15,000ft long bicable ropeway of 160 tons per hour capacity, to a stockpile, 450ft by 150ft, at the dam site. The stockpile is divided into six compartments for the storing of the various sizes of aggregates.

Underneath the stockpile, there is a 7ft by 7ft reclaiming tunnel, and the material is discharged through automatic gates to a 30in wide conveyor of 200 tons per hour capacity, which discharges the materials into the six compartments of a receiving bin placed at the head of the cooling chamber. At a distance of 330ft from this bin is the batching and mixing plant, with a capacity of 120 cubic feet per hour, and three mixers of 2 cubic yards each. The concrete ingredients are given in the table, which also gives the temperatures on which the design of the cooling plant is based.

It is stipulated that the pouring temperature of the concrete mix should be 60 deg. Fah., irrespective of the outdoor atmospheric conditions, so that a mixing temperature in the neighbourhood of 55 deg. Fah. is required. Cooling of the aggregates takes place during transport from the receiving bin to the six compartments on top of the batching plant. The stones are cooled by chilled water to an average temperature of 40 deg. Fah., and the sand by air blast, to 72 deg. Fah., the mixing water being available at a temperature of 37 deg. Fah. Cement is not cooled. On this basis, a pouring temperature of 60 deg. Fah. is achieved, after allowing for temperature rise during transport from the batching plant to the dam site.

The aggregate receiving bin is separated from the storage bin on the batching plant by an insulated chamber 330ft long by 33ft wide and 10ft high, the last 100ft of which is on an incline. In this chamber, six troughed conveyor belts transport the six classes of aggregate into the respective compartments of the batching plant storage bin. The cooling of the coarse aggregates is by a combination of chilled water sprays at 40 deg. Fah. and 36 deg. Fah., and by inundation. To remove free moisture, the conveyors are taken over a loop, and the aggregate passes through air jets as it falls on to a steel grid. The fine aggregates are cooled by dry air at a temperature of 42 deg. Fah. All aggregates, coarse and fine, are exposed to chilled water and chilled air respectively, for twenty to twenty-five minutes.

Concrete Ingredients

Type	Size	lb per hour	Assumed temperature, deg. Fah.
Coarse aggregate	6in–3in	119,000	100
Coarse aggregate	3in–1½in	66,600	100
Coarse aggregate	1½in–¾in	66,600	100
Coarse aggregate	¾in–¼in	57,200	100
Fine aggregate ..	¼in–¼in	57,200	100
Fine aggregate...	¼in–100 mesh	109,400	100
Water	—	24,000	85
Cement	—	72,000	110

Chilled water is produced at the rate of 1600 gallons per minute. 1000 gallons of this chilled water, at an initial temperature of 36 deg. Fah., are used in a large air-washer to cool the air required for cooling the fine aggregates and also for the cooled water used to mix the concrete. The rest is used in cooling the coarse aggregate. The spray and inundation water from these belts is collected in a trough underneath the belts leading into a series of settling tanks to remove any silt washed from the aggregates. The final settling tank has a fine mesh screen to prevent any possible return of silt into the system. Chilled air is circulated continuously by eight fans, each of 27,000 cubic feet per minute capacity.

The complete conveyor belt arrangement works at abnormally low speeds, and all belts from the stockpile, the tunnel and the receiving conveyors are controlled by push-button switches with interlocking. The exposed parts of the cooling chamber and the batching plant bins are insulated with 3in of cork.

The first batch of concrete was poured on May 4, 1952, and during the following four weeks, some 20,000 cubic yards of concrete were placed in the foundations of the dam. May is the hottest month of the year in Bombay, with temperatures in the neighbourhood of 95 deg. Fah., but the plant is stated to have worked satisfactorily, recording pouring temperatures as low as 58 deg. Fah. All work was stopped during the monsoon. So far about 100,000 cubic yards of concrete has been placed. The cooling plant was designed, supplied and installed by Volkart Brothers, of Bombay, in co-operation with the main contractors for the dam, the Hindustan Construction Company, Ltd.

EMPLOYMENT OF THE OLDER AGE GROUPS.—A film made for the Canadian Department of Labour which deals with the economic and social problems associated with the provision of employment for the older classes of men and women is now available for showing in this country under the sponsorship of the Ministry of Labour and National Service. This film encourages employers to remove age barriers when engaging new workers, and pays tribute to the dependability of older men and women, at the same time drawing attention to the valuable contribution they can make to industrial productivity. The film can be hired for a small charge from the Central Film Library, Government Buildings, Bromyard Avenue, London, W.3.

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LIGHTWEIGHT MERCHANT SHIP MACHINERY

Ever since the days of Elizabeth I, if not before, the design of warships and merchant ships has been related; and since the time in the last century when the Admiralty, (rather reluctantly, perhaps) turned from sail to steam, the Navy has been heavily indebted to the Merchant Service for advances in practice and ideas, and the Merchant Service as heavily indebted to the Navy. Indeed, those two departments of engineering, naval and merchant marine, are almost ideally disposed to stimulate one another. For the demands made upon sea-going machinery in the Navy and the Merchant Service, though similar in many respects, differ provocatively in others. Machinery for the two services has been forced to develop along different courses. But those courses do not so much diverge as run parallel. Again and again, therefore, an advance made along one of them can suggest that an advance ought to be made along the other and can indicate what is the line of thought that ought to be followed in making that advance. In the past, the Merchant Service and the Navy adopted steam turbine propulsion more or less simultaneously. But the Merchant Service led in the use of gears in the " Vespasian "; and once more in the " King George V " it led the way towards the use of higher steam conditions. When, however, it turned to diesel propulsion the Navy did not follow, except for auxiliaries and the propulsion of small craft and submarines. To-day, the boot may be on the other foot. The Navy is proving critical of the steam machinery commonly installed in merchant vessels, and it is suggesting that it could be substantially lighter and cheaper than it conventionally is without loss of essential reliability.

The Navy's contentions, which were openly voiced by Sir Denys Maxwell, Engineer-in-Chief of the Fleet, at a dinner last November are not, of course, wholly new. Suggestions have been made from time to time that mercantile machinery ratings were open to improvement and that weights of machinery could be lowered. That those suggestions had formerly little effect can be traced partly to the fact that steam turbine propulsion plant, the only plant in larger powers in which the Navy is interested, was only used for a minority of mercantile vessels. To-day, however, for reasons which need not be mentioned here, interesting though they are, it is being freely adopted for the propulsion of large tankers, a class of vessel in which the Navy, for obvious reasons, takes much interest. Of course, the argument often used in the past that there is a big difference in the jobs that naval machinery, on the one hand, and mercantile machinery, on the other, have to undertake still applies in full force to-day. Naval machinery is designed for a high maximum output at which economy is not very important and much lower economic cruising powers which will normally be used; mercantile machinery for economy at that output close to the maximum at which the engines will normally be run on every passage. Reliability is important to both. But warships spend much time in port, whereas the object of a shipowner is to have his ships as constantly at sea as possible. In consequence, the shipowner is likely to stress more highly than the naval engineer (who, incidentally, has more manpower available on board to undertake it) the need to reduce maintenance to the minimum. The Navy consistently makes use of hollow propeller shafts. But the need for reliability in service is less extreme than it is in merchant service, for all the more important naval vessels have more than one propeller. By contrast, many merchant ships have single screws, so that a shaft failure involves, at the least, heavy salvage expenses and, at most, the possibility of total loss. Moreover, when a merchant vessel is in ballast the propeller and its shaft operate under conditions more severe in some respects than are met by warships. Nor, it may be added, would reduction in the space occupied by engines, a matter of much importance in a warship, bring much benefit to shipowners under existing tonnage regulations relating to machinery spaces. Those and several others are all old points of discussion. What has given naval arguments new force is the suggestion that lighter weight machinery, despite its higher rating per ton, would prove cheaper in first cost! For the disparity in weight has grown very large. Sir Denys, for instance, quoted the specific weight of steam plant for a modern freighter or tanker at between 150 lb and 200 lb per shaft horsepower, and that of modern naval machinery of the same power at 30 lb to 45 lb per shaft horsepower. Those figures may exaggerate the true disparity. Yet it appears that the sheer cost of the raw material in steel and other metals of the heavier plant may outweigh the cost of the advanced techniques of construction necessary to achieve lightness; and naval men maintain that lighter weight machinery need prove no less reliable in service nor require undue attention to maintenance.

No marine engineer nor shipowner is going to accept these naval contentions " out of hand." But they certainly deserve, and are as certainly getting, serious study. For the Merchant Marine is not without the means of securing sufficient facts upon which to reach a correct judgment. It is, for instance, reasonable to suppose that the Admiralty is proving willing to reveal pertinent details of the actual performances of naval machinery in service. Again, the improvement in the design and performance of marine turbine machinery is the constant aim of machinery builders, and they supply both the Mercantile Marine and the Navy with machinery. Once more, Pametrada, the research station they support, only recently had under test machinery built for " Daring " class destroyers. That station, whose annual reports indicate that it has work in hand, amongst other matters, upon condensers and gearing and, indeed, upon lightweight machinery in general, should certainly be able to contribute opinions of great weight. So, too, should Lloyd's Register. For it has so unrivalled a knowledge of the performance (and the failures) of ships and engines that it may be able to draw valuable conclusions, even, perhaps, conclusions as to the desirability or otherwise of modifying its own rules if they stand in the way of the adoption of lighter weight machinery. In the end, of course, the decision for or against the naval contentions will lie, not with such bodies nor with individual engine builders, but with hard-headed shipowners and the engineers upon whom they rely for advice about the economical operation of ships. But whatever the outcome, nothing but good is likely to emerge from the various discussions that are now going on. They demonstrate once more how advance can be stimulated when naval and mercantile trends of thought impinge upon one another. In the past it has often been the Merchant Navy that has led the way. Maybe it is now the turn of the Navy.

THE GOVERNMENT AND THE SUPPLY OF TECHNOLOGISTS

It has been a matter of no little concern to many thoughtful people in this country that our output of technologists is far from being as large as it should be. This concern was shared by the late Labour Govern-

ment and is equally shared by the present one. The importance of putting the matter right was stressed in Parliament some weeks ago by the Postmaster-General, who dwelt on the need for prompt action to meet the requirements of the Commonwealth and Empire and, not least, those of this country. He agreed that greater facilities ought to be provided for training, and he was sure that the Lords listening to him would be glad to know that the Government intended to make, as early in this New Year as possible, a definite statement of a scheme for the expansion of technological education different from that proposed by the Labour Government, whose proposal for a Royal College of Technology, it was announced some months ago, has been dropped. That promise the Government fufilled before January was out, when the good news was announced by the Financial Secretary to the Treasury that it was the intention to increase the number of students at the Imperial College of Science and Technology at South Kensington to 3000—almost twice as many as at present—during the five years 1957–62, and to aim at so doing around the present sites of the College.

Many conflicting factors are involved in formulating schemes for the improvement of the country's system of technological education. Ought, for instance, the increase in training capacity to be centred in a single location or should there be several such institutions ? The answer may be expected to favour several, not only for the important strategic reason that precious eggs must not be all in one basket, but also because specialist study of particular technologies may be best centred in different parts of the country. Moreover, as previously suggested in these columns, it is desirable that any technical college chosen to be advanced in status to a technological college should be close to an existing university, and the selection aided by the wise advice of our leading engineering societies. Thoughtful planning will, too, be called for in adapting existing institutions to so greatly enlarged a task. It will include the provision of greater space to carry the new buildings that may be necessary, the enlargement of the teaching staff, and the appropriate co-ordination with the local university. All this will no doubt be harder to do in some localities than others. At the Imperial College the problems of expansion to be solved by the Governors of that College have been obvious for some time, and rendered the more difficult by the need during past years for its immediate neighbour, the Imperial Institute, to add to its income by temporary leasing arrangements with a variety of tenants having very different objectives—leading to a jigsaw puzzle planning of land much in demand for more important purposes. The parliamentary debate that gave rise to the official declarations noted above arose from a suggestion by Lord Falmouth that if, in carrying out the recommendations of the recently issued Tweedsmuir report, some or all of the activities of the Imperial Institute are moved to another site, the space so vacated could be appropriately used to meet the urgent needs of Imperial College. It was notable that in the report, unanimously adopted by the Committee, its members frankly suggested that if their proposals could not be substantially accepted as a whole, and with reasonable speed, they could but advise that the Institute be closed and the premises put to some other use.

In recent years many countries have initiated, or have substantially expanded, their secondary industries and have thus met a number of their more pressing needs. As an exporting country we must therefore be ready to devise improved forms of our products, or better still—by sheer inventive power—produce commodities possessed of novel and alluring merits. We have a high reputation for scientific discovery and for inventive capacity, but we need more technologists to cover, as well as we should, subsequent application and development. It may be a debatable point, but the suggestion has been put forward that part of our difficulty has grown from the old custom of seating even leading technologists in " back rooms " rather than " board rooms " ; though that may now be little more than a regrettable feature of past years from which U.S.A. and Germany freed themselves more quickly than we did. In any event, it is pleasant to find Professor Willis Jackson remarking, in a recent public lecture, that " an increasing proportion of the directors of electrical engineering firms are being drawn from men who have progressed through a succession of scientific, technical and administrative positions in the factory." Though, as he naturally adds, this end cannot be achieved by means of scientific and technical knowledge alone. We hope that when the Government's policy is fully declared, it will prove to be one capable of rapid fulfilment in each of the chosen centres. The times are urgent and there should be no avoidable delay in a matter that touches so very closely our economic balance of trade with overseas customers.

Literature

Statistical Theory with Engineering Applications. By Professor A. HALD. London : Chapman and Hall, 37, Essex Street, W.C.2. Price 72s.

THE aim of this book in the words of its author is " to provide a fairly elementary mathematical treatment of statistical methods of importance to the engineer in his daily work." It is the reviewer's opinion that this description and the title of the book itself are too modest. They give the impression that this is just another book on statistics with a more or less practical viewpoint. In fact, it is a surprisingly comprehensive and up-to-date exposition of fundamental statistical theory, logically developed, well illustrated with practical examples, and of interest to many kinds of specialist besides the engineer, not least the mathematician. The book seems particularly suited to the reader whose interest has been aroused by books of a more general character, and who, while aware of the benefits which could result from his applying statistical methods, feels that he lacks the background necessary for so doing.

Anyone mastering the contents of Professor Hald's book will certainly have gained a very respectable statistical equipment. However, it should be emphasised that this book is for the serious student. Although the mathematical requirements are modest enough, not more than elementary calculus being necessary, the reader would be well advised to follow the author's development completely and this is a task requiring some stamina (there are 760 pages).

A real virtue of this book is the conscientiousness with which important results in the theory are illustrated with practical examples (which do not look as though they have been specially cooked for the purpose). These examples are of an industrial sort for the most part, and include data dealing with such diverse topics as the particle size distribution of sand after grinding in a tube mill, the rate of steam production in a boiler, the tensile strengths of cables, the compressive strength of cement-mortar cubes, and chemical process control. This is a change from the familiar biological-agricultural type of illustrative material.

The opening chapter deals with probability theory, in contrast with other writers who prefer to discuss frequency diagrams, &c., first. It discusses the concept of random variation and proceeds to the consideration of the relative frequencies of occurrence of events. Having familiarised the reader with the fundamental properties of frequencies by way of a practical example, the writer leads him to formal definitions and axioms followed by the basic addition and multiplication formulæ. The treatment is very convincing ; in fact, it makes the subject of probability appear simpler than it is. Applications of this theory are found in the binomial and multinomial distributions. Professor Hald then goes on to treat frequency diagrams and graphical and tabular representations of observations. In dealing with more complex multidimensional distributions, the use of punched-card methods and coding procedures are discussed with admirable illustrations. Then follow definitions and fundamental properties of the variance and co-variance, mean values and cumulative distribution curve. This section is not fundamentally different from other treatments, but the clarity of presentation is commendable. There is a chapter on the normal distribution and its properties, as there ought to be considering its place in statistical theory. There is a very comprehensive treatment of the truncated normal distribution which the reviewer has not seen in any other book. This distribution arises when we are not able to sample the whole population, but only a part of it ; this happens when the individuals are sorted according to some criterion and the sample is taken after sorting has been carried out. The chapter also introduces the reader to probability paper—a type of diagram used extensively in the succeeding chapters. There is an interesting chapter on skew distributions with particular reference to the log normal curve, and containing a section on transformations, i.e. devices for making skew distributions normal, such as $\log x$, $\sqrt{x}$, with good examples.

Having laid the foundations, the writer introduces the reader to important mathematical statistical concepts, such as the idea of a sampling distribution, illustrated by its application to the mean and variance, the Law of Large Numbers and the Method of Maximum Likelihood. The latter is very condensed and liable to give trouble to the thoughtful student.

The chapter on " Distribution of the

Mean " gives the reader a critical appreciation of the meaning of a significance test, by introducing him to the work associated with the names of Professors J. Neyman and E. S. Pearson. Briefly, the basic ideas are to the effect that the errors resulting from a significance test are of two kinds, respectively, rejection of the test hypothesis when it is true, and acceptance of the test hypothesis when it is false. It is the job of the statistician to employ tests which give the highest probability of making a correct decision, by minimising the latter sort of error for a specified value of the former. The probability of rejecting the test hypothesis when it is false is called the power of the test. It is too often the case that in applications errors of the first kind only are considered. Many control charts have been constructed with only this kind of error in mind (Professor Hald considers this application). The reasons for this lack of appreciation are, first, that the ideas require the effort of considering basic conceptions, and, secondly, that many treatments of the subject are on too abstract a level. The merit of a book to a large extent depends on the degree to which the writer manages to convey these ideas. In this respect Professor Hald scores very good marks indeed. He ignores the higher flights of theory and contents himself with hammering the fundamental ideas home by way of calculating power functions in simple cases. It is then possible for him to use the power concept in subsequent chapters on the χ^2, variance-ratio and t tests. This would appear better than dealing with this theory nearer the end of the book after the various tests have been introduced. The same chapter mentions confidence intervals for the first time and there is a useful section dealing with the variance of a function of observations (*cf. Statistical Methods in Research and Production* (ed. O. L. Davies)).

Succeeding chapters deal in a thorough manner with the χ^2 distribution with particular reference to the partition theorem on which the analysis of variance depends, the distributions of variance and range, and the t and variance-ratio distributions.

Control chart ideas are introduced in various places and not in any particular chapter. There is a chapter, however, on " Statistical Control." This is of particular interest to all who use control charts. It is concerned with the idea of randomness in a sequence of observations and tests for detecting departures from randomness. In a series of observations extended in time, such as a control chart, there may be trends upwards or downwards, periodic fluctuations, &c. If a number of increasing observations occur, this " run " may lead us to suspect non-randomness in the form of an upward trend. Tests are given to determine whether the runs that occur are consistent or not with hypothesis of randomness.

The treatments of the Analysis of Variance and Regression are logical culminations of the preceding work. They are the most powerful of statistical tools, and Professor Hald has rightly devoted a considerable amount of space to them. It is easy for the beginner to acquire a familiarity with these techniques by reference to a number of books, good, bad and indifferent, on statistics. All will go well until he has to interpret (say) certain significant interactions or the physical meaning of a regression relationship. If he consults a professional statistician he is liable to be told primly that it is all a matter of " mathematical models," and unless the statistician in question is a particularly good teacher the questioner is most likely to come away feeling that the subject is best left to those who have sufficient mathematics to understand it. Now Professor Hald supplies this much-needed guidance within a fairly elementary mathematical framework. This does not mean that his treatment will be found all plain sailing, but that is because this is no trivial subject, and not due to any defect in the presentation. The Analysis of Variance is an arithmetical apparatus in which statistical hypotheses are tested, e.g. that the means of certain groups are equal. Such hypotheses correspond to physical situations and the mathematical model is the exact specification of the statistical hypothesis, and in fact is a clear way of thinking about the physical conditions. The author proceeds to progressively more complex situations, dealing with each meticulously and with due regard to practical illustrations. At the end of a study of this chapter the reader should have a genuine knowledge of what the Analysis of Variance is about, as well as how to set about the necessary computations.

The following chapter is on the designs of sampling investigations and experiments. This is only a short account, but justified in view of the fact that these are special topics on which a good deal has been written. The first part deals with stratified random and two-stage sampling with due regard to cost factors. In the design of experiments part, randomised blocks, Latin Squares and factorial experiments are discussed.

In the first chapter on Regression Analysis the author at the outset distinguishes between regression and correlation analysis, which is by no means common in other books. In the latter case both variables are random, but in the former only one variable need be random. Thus regression analysis is applicable to experiments in which one set of values have been deliberately chosen. Mention is also made of confluence analysis which is a method developed in the economic field. The treatment of linear regression is linked with the preceding work in the Analysis of Variance and a number of examples are given and the method of computation clearly set out. A section on the solving of a regression equation with respect to the independent variable is noteworthy as is also the full examination of the case where the variance about the regression line is proportional to a given function of the independent variable. There is much on the transformation of regression curves into linear forms. Professor Hald then refers to the problem of different regression interpretations of the same data. Following an excellent illustrative example, he makes the vital observation that one should be very careful with the interpretation and application of formulæ that are not firmly based on professional knowledge. He emphasises the same point again later in the development. This chapter also contains an able exposition of the technique usually referred to as the Analysis of Co-variance.

In the chapter on " The Two-Dimensional Normal Distribution," the author deals with a number of standard results. This is followed by a chapter on more complex correlation and regression problems. There is mention of a situation which often arises when two variables in a multiple regression study do not vary independently and the relative values of the corresponding coefficients are meaningless. The technique for coping with a linear regression analysis with m independent variables is clearly set out in the Doolittle scheme ; a specimen numerical example with four independent variables is worked out. Non-linear regression is considered and the chapter ends with short sections on Growth Curves and Time Series.

The placing of the treatment of the Binomial and Poisson distributions near the end of the book instead of the beginning is unusual, but, in the reviewer's opinion, justified, since a thorough treatment requires a considerable statistical background. Professor Hald's theoretical exposition is excellent. Approximation formulæ are dealt with very thoroughly. On the practical side reference is made to the Control Charts for proportion and number defective, and various sampling inspection schemes are discussed. In the chapter on the Poisson Distribution, a derivation of the distribution is given from the standpoint of probability calculus, and reference is made to the historic work of Professor Hald's fellow-countryman, A. K. Erlang, on telephone systems.

There is a short chapter on the application of χ^2 to contingency tables and another on Sequential Analysis, where Wald's Probability Ratio test is given for the mean and standard deviation. The book closes with a chapter on " The Main Points of a Statistical Analysis," in which a number of important general principles for the applied statistician are laid down. Professor Hald's " last words " are worth quoting : " Further, it must be kept in mind that a satisfactory agreement between the observations and the test hypothesis is not equivalent to a proof of the hypothesis. The agreement only means that *the hypothesis has not been disproved*, i.e. that so far the hypothesis can be accepted as a working hypothesis—in line with many other hypotheses—and that the collection of more observational data may perhaps lead to modification or rejection of the hypothesis."

The reviewer has not detected any serious typographical or other errors ; the format, diagrams, &c., are excellent, and especially to be commended is the author's placing of important formulæ in " boxes." But particularly deserving of praise are the extensive bibliographies, with comment, throughout the book, helping the reader to follow-up any particular interest if he so desires. There is one omission here that is worth mentioning, and that is in the chapter on " Statistical Control," which contains no reference to the fundamental paper of Kermack and McKendrick on the theory of runs (*Proc. of the Royal Society of Edinburgh*, 1937). The English is clear and direct, although the book is a translation from the Danish.

Published in conjunction with this book is a separate volume, *Statistical Tables and Formulas*. It contains a survey of the most important results given in the textbook and a clear explanation of how the tables should be used in conjunction with these results. The book contains, *inter alia*, the t, χ^2 and range distributions, extended as compared with previously published tables. The author states that linear interpolation both with respect to probability level and number of degrees of freedom will be sufficient for most practical purposes. Distribution and power curves may be readily drawn from the tables. A useful table is " Two-Sided 95 per cent and 99 per cent Confidence Limits for the Probability θ in the Binomial Distribution," and the inclusion of tables on the truncated normal distribution is noteworthy. Other standard statistical functions are tabulated, and, in addition, tables of squares, logarithms, &c., are given. The volume should be found sufficient for most users. Not the least of its virtues is that the tables are easy to read.

Prestressed Concrete. By DR. KURT BILLIG. London : Macmillan and Co., Ltd., St. Martin's Street, W.C.2. Price 36s.

DR. BILLIG'S contribution to the small but growing number of text books on prestressed concrete does not greatly advance

knowledge of this subject. In some respects it, indeed, may be considered to hamper it. It attempts in some 470 pages to cover the whole field—the history, development, methods and processes, tests, calculations, &c., and it concludes with a draft bibliography. Yet at the end of reading it one is left wondering whether this number of pages has really been adequately filled. The book also contains some thirty pages of references. The reviewer feels that the book would have been more useful had these sources of information been studied more fully. For it is clear that a number of the descriptions in the book of prestressing processes are by now out of date and have been so for some years. The author is obviously biased towards pre-tensioned work and by far the greater part of the book is devoted directly or indirectly to this aspect of the subject, which from a civil engineering point of view is less important than that of post-tensioned work. His descriptions of the latter are brief and unhelpful. Unfortunately, Dr. Billig's experience of pre-tensioned work (to judge from the book) seems to have been limited to that of an experimental bed and his description of large-scale production is not only inadequate but sometimes erroneous. It would indeed be a pity if a student's or engineer's first impression of prestressed concrete were to be obtained from these descriptions.

The part of the book dealing with design is short and uses symbols which are not familiar to British engineers and seem to be Continental in their origin. Design problems which are dealt with separately would have been more useful if they had been worked over by the author rather than being direct translations from books by various Continental authors. The use of the late Professor Mörsch's example of the design of an autobahn bridge (1943) is not helpful in 1953.

Dr. Billig's contribution to the subject, in his draft code of practice that he proposes, is an attempt to set down the do's and don'ts of this subject. It is clearly based, as are certain of his earlier chapters, on the German draft code (1945) for the same subject and as such starts on a good basis, but in certain respects is misleading and restrictive. Existing proved methods of prestressing would be excluded for no apparent valid reason if his code was adopted.

In conclusion it seems a pity that such an excellently produced book contains so little material which would be helpful to the student or practising engineer.

The Essentials of Fluid Dynamics. By LUDWIG PRANDTL. London: Blackie and Son, Ltd., 16–18, William IV Street, W.C.2. Price 35s.

THERE is no German scientist working in the field of the mechanics of fluids whose name is more respected than Professor Prandtl's, and British and American students of hydraulics, aeronautics and meteorology have for many years made great efforts to make and keep themselves acquainted with his publications. This book is a translation of the latest edition of his standard treatise and may be considered the most comprehensive statement in English of his teachings.

A generation ago interest in Prandtl's field and, consequently, the influence of his work were confined to a narrow circle consisting in the main of other researchers; few engineers saw the link between his theory and their practical problems. This link between theory and practice has now been established, and it is continually being strengthened by the joint endeavours of both sides. More engineers are studying the theory of the mechanics of fluids, and the scientists show an ever-increasing appreciation of the engineer's needs. In this spirit Prandtl has included in his book many examples of the practical application of the various theoretical conclusions.

The method of presentation is, in each chapter, to start from the fundamentals and to build up the subject to the level appropriate to the advanced student, with mathematics presented separately and kept, as far as possible, out of the explanatory statements.

The book deals, in its successive chapters, with the equilibrium of fluids, with the dynamics of frictionless fluids, with viscous fluids, turbulence and fluid resistance, with the dynamics of gases, and finally with a selection of special topics. The many practical applications include the flow of water in open channels and in closed conduits, pumps and turbines, in waves and around blades; the mechanics of oil in lubricating films; aerofoils and propellers; wind pressure on buildings; supersonic velocities; cavitation; pneumatic and hydraulic transport; and some problems of heat transfer and of meteorology.

The translation, competently carried out by Miss W. M. Deans, has been checked by Professor H. B. Squire, who, with his colleagues, has also added British and American references to Professor Prandtl's full Continental bibliography. The publishers are to be commended for producing a book which is pleasant to handle and well produced, at a price within reach of a student's pocket. This excellent work deserves wide circulation among students at all levels of achievement, including progressive practising engineers with a desire for a clear understanding of fundamentals and for a better knowledge of the useful advances in many directions quoted by Prandtl.

SHORT NOTICES

Colliery Rope Haulage and Rope Splicing. By John Kimber, jun. London: Colliery Guardian Company, Ltd., 30 and 31, Furnival Street, E.C.4. Price 30s.—The author has worked many years as a colliery ropeman, and in this book he has incorporated a considerable amount of information based upon his own practical experience. The book is arranged in three main sections. The first section on colliery rope haulage deals with ropes and their construction, care, handling, splicing, breakage, repair, maintenance, &c. In the second section on sheave work there are described terminal return sheave frames, sheave constructions and types, guards, &c. The third section of the book gives a considerable amount of miscellaneous information and formulæ of particular use to rope smiths. The text matter is amply supplemented by many excellent drawings and diagrams, which both simplify and give the reader a clear understanding of all aspects of the particular subject being dealt with. A rope smith plays an important part in the efficient and economic running of rope haulage in a colliery; and, although most of his work is of a practical nature and is in the main gained by first-hand experience, the fund of detailed information given in this comprehensive book will be of considerable value both to students and all others concerned with this aspect of mine working.

Handbook of Engineering Fundamentals. Second edition. By O. W. Eshbach. London: Chapman and Hall, 37, Essex Street, W.C.2. Price 80s.—This book deals with the theory and basic principles of mathematics, physics and chemistry, and contains all the commonly used mathematical and physical tables; the properties and uses of engineering materials; the mechanics of solids and fluids, and a section on engineering law. For those occasions when it is necessary to clarify one's concepts of some branch of engineering practice, a book of this kind can be recommended—the laws and theories are well presented, the subject matter well grouped in sections, and the whole is supported by a well made index.

The handbook is of American origin, and doubtless this is the reason for the almost entire absence of reference to British books in the bibliographies which appear at the end of each subsection. The absence of references to British Standards may also be considered a disadvantage, from the point of view of the reader in this country.

In this edition the text has been revised and enlarged; improvements include the standard structural sizes for aluminium, and the inclusion of data on offsets and tangents. The tables of standards and symbols have been brought up to date, and the M K S system of units incorporated into the formulæ and conversion tables. Theoretical and applied mechanics has been divided with reference to the field of application; the mechanics of rigid bodies includes statics, kinematics, kinetics and aspects of frictional phenomena; the section on fluid mechanics is in two parts, (*a*) incompressible fluids with emphasis on hydraulics, and (*b*) aerodynamics, with emphasis on design and performance of aircraft. Eshbach is a worthy addition to the engineer's bookshelf and will be found useful in conjunction with all kinds of technical literature.

Letters to the Editor

(We do not hold ourselves responsible for the opinions of our correspondents)

SIMPLICITY IN GEARS

SIR,—I am, to say the least, surprised at Dr. Merritt's self-contradictory remarks under the heading "Simplicity in Gears," of January 23rd. He appears, in the first part of his letter, to be proving that the British Standards for gears are of very little use, and yet he goes on to say, "As it happens, gears designed in accordance with British Standard rules are generally satisfactory."

I and many other people would agree that there are applications when the British Standards are not satisfactory, but the number of times where they are useful far outweigh the "specials" and therefore prove the usefulness of the specifications.

The "pseudo-textbook air" has been applied to a number of British Standard Specifications and I consider that it is very useful in cases where a column of figures could not possibly cover the whole story. It leads people to think in a certain way and, therefore, produce the uniform results which is the essence of standardisation.

When one considers all the work Dr. Merritt is doing for standardisation generally and also on his speciality of gear problems, it does not seem possible that he should, in effect, say "all my work on standardisation in the past—all I am doing now and all I intend to do in the future is of no use."

R. E. MILLS
A.M.I.Prod.E., A.R.Ae.S.

Bristol,
February 16th.

THE ENGINEER Buyers Guide

THE 1953 edition of "THE ENGINEER Buyers Guide" has just been published and one free copy is being dispatched by post to all subscribers on our lists. Arrangements have also been made for all regular readers who obtain THE ENGINEER through newsagents to receive a copy, which should be delivered to them with the current issue. Any subscriber or regular reader not receiving a copy should write to The Manager, THE ENGINEER, 28, Essex Street, Strand, London, W.C.2. Extra copies are obtainable at 5s. each, including postage.

The Testing of Concrete Mixers

By R. H. H. KIRKHAM, B.Sc., Ph.D., A.M.I.C.E.*

No. II—(*Continued from page 235, February 13th*)

THE EFFECT OF THE MATERIALS USED AND MIX PROPORTIONS

The use of concrete of a very low degree of workability leads to several important advantages. The use of dry concrete, however, has introduced difficulties when using mixers which were essentially designed for, and have given satisfaction with, wetter and more workable mixes. Tests have been made on a 7NT concrete mixer, selected as being one of a type widely used to investigate the influence of the materials used and the mix proportions on the efficiency of the mixer.

THE TESTS

IN order to measure the performance of the mixer, the uniformity of the concrete in each mixed batch was assessed by analysing eight samples withdrawn consecutively during discharge to determine the water/cement, sand/cement and gravel/cement ratios.[1] The mix was repeated with mixing times ranging from 5 to 270 seconds so that the rate of output could be measured in terms of the time required to produce concrete of as uniform a quality as the mixer was capable of producing.

Five series of tests were made, the details of which are given in Table II. The mix for the first series was chosen as an average mix for which the mixer was likely to be used in road construction and, in the remaining series, the mix was altered to examine the effect of varying (1) the proportions, (2) the type of aggregate, (3) the maximum size of the coarse aggregate and (4) the workability of the concrete.

TABLE II—*Details of the Mixes Used in the Tests*

Series	Mix proportions	Water/cement ratio	Compacting factor[2]	Type of aggregate	Max. size of coarse aggregate (in)
1	1 : 2½ : 5	0·60	0·85	River gravel	¾
2	1 : 1½ : 3	0·42	0·85	River gravel	¾
3	1 : 2½ : 5	0·65	0·85	Granite	¾
4	1 : 2½ : 5	0·55	0·85	River gravel	1½
5	1 : 2½ : 5	0·50	0·76	River gravel	¾

The size of the mixes was chosen so that the mixer was loaded to deliver sufficient concrete to give about 7 cubic feet when fully compacted (dry density 144 lb per cubic foot) and, for the 1 : 2½ : 5 mixes, therefore, the equivalent of a one bag mix was used, while for the 1 : 1½ : 3 mix the size of the batch was made the same (1019 lb). In order to obtain repeatable results the mixing procedure was identical for each series of mixes and the charging of the mixer was timed, as described below, in such a way that small differences in the rate of loading would have little effect. The aggregate and sand were thoroughly dried before use, and they and the cement were batched by weight and loaded into the mixer skip with the cement and sand sandwiched between two equal layers of gravel. The water tank on the mixer was carefully calibrated. Since the flow of water was fairly slow, it was started first and, when the drum was completely wet, the hopper was raised and the mixer charged. The flow of water continued after all the solid materials were in the drum and the full loading operation took thirty-five seconds, so that the mixing time was taken to begin thirty-five seconds after the commencement of charging.

In order to provide a standard with which the results could be compared the method of analysis was also used to assess the uniformity of concrete thoroughly mixed by hand. Five identical mixtures were made with the same proportions as the mixes in series (1), using river gravel of ¾in maximum size, and eight samples were taken from each mixture and their proportions estimated. The procedure was repeated with mixtures made with river gravel of 1½in maximum size having the same proportions as the mixes in series (4). For this hand-mixed concrete the time taken in mixing was considered to be much less important than the achievement of as uniform a mix as possible and each batch was turned over three times from each of four directions both before and after the water was added. This standard would not be achieved in practice, but it can be regarded as a measure of the uniformity which can be obtained in a batch with the materials used.

* Road Research Laboratory.

THE EFFECT ON THE MIXING TIME AND ON THE UNIFORMITY OF THE BATCH

The variations in the standard deviation of the water/cement, sand/cement and aggregate/cement ratios, calculated for the eight samples from each batch of concrete, are shown in Figs. 9, 10 and 11 respectively. Considering all five series of tests, the standard deviation of each of the three ratios appears to reach a constant value after about eighty-five seconds of actual mixing, and it appears that the time required to mix a batch as uniformly as the machine is able is independent of the mix proportions.

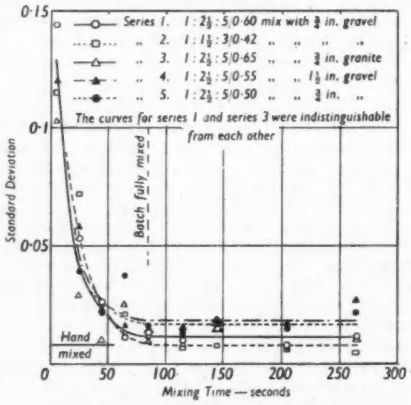
Series 1. 1 : 2½ : 5·0·60 mix with ¾ in. gravel
2. 1 : 1½ : 3·0·42 " " " "
3. 1 : 2½ : 5·0·65 " " ¾ in. granite
4. 1 : 2½ : 5·0·55 " " 1½ in. gravel
5. 1 : 2½ : 5·0·50 " " ¾ in. "
The curves for series 1 and series 3 were indistinguishable from each other
Batch fully mixed
Hand mixed
Standard Deviation
0·15
0·1
0·05
0
50
100
150
200
250
300
Mixing Time — seconds

Fig. 9—The Within-Batch Variation of Water/Cement Ratio with Mixing Time

The uniformity of the batch after this time does, however, depend upon the proportions. Only for the rich mix (series (2)) was the standard deviation of the water/cement ratio (Fig. 9) as low as that of concrete thoroughly mixed by hand. With a lean mix of the same workability the water/cement ratio was more variable both when a river gravel (series (1)) and when a crushed granite aggregate (series (3)) was used. The variability was further increased when either the maximum size of the coarse aggregate was increased (series (4)) or when the workability was reduced by reducing the water/cement ratio (series (5)). Modern specifications, which call for the use of lean, dry mixes with 1½in or larger aggregate do therefore lead to more difficulty in producing from the mixer a concrete of uniform water/cement ratio and therefore of uniform strength.[2]

Generally the sand and cement were mixed more uniformly by the mixer than were the water and cement. The standard deviations of the sand/cement ratio (Fig. 10) for the rich mix and for the lean mix with ¾in granite aggregate were actually less than that of hand-mixed concrete, while that of the lean mix with ¾in gravel aggregate was very little greater. The effect on the sand/cement ratio of a drier mix or a coarse aggregate of larger maximum size was the same as that on the water/cement ratio, however, in that they led to more variability.

The variability of the coarse aggregate/cement ratio is shown in Fig. 11. As for the water/cement ratio, only the standard deviation for the rich mix was as low as that of concrete thoroughly mixed by hand. With a lean mix of the same workability the aggregate/cement ratio was more variable and the variability was more when the aggregate was a river gravel than when a crushed granite was used. Reducing the workability of the mix did not increase the variability of the gravel/cement ratio, as it did that of the water/cement ratio, but the use of aggregate of a larger maximum size caused a very large increase in the standard deviation. It is, of course, more difficult to obtain a uniform mix of low or very low workability with the 1½in gravel as is shown by the results of hand mixing. The uniformity of the water/cement and sand/cement ratios of hand-mixed concrete using ¾in and 1½in gravel were very similar, but the variability of the gravel/cement ratio was increased by the use of the larger aggregate. The increase in the variability of the concrete from the mixer, however, was still considerable when it was compared with that of hand-mixed concrete using the larger aggregate. The aggregate/cement ratio was thus more variable when a leaner mix or a rounder or larger aggregate was used (that is when a mix likely to lead to more segregation was employed), and most of the variability of the aggregate/cement ratio can probably be attributed to segregation either during mixing or discharging. The specification of lean mixes with large aggregates does lead, therefore, to more variation in the workability of the batch.

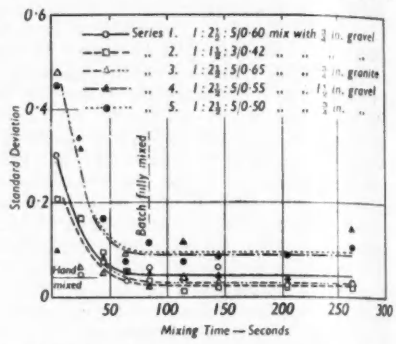
Series 1. 1 : 2½ : 5/0·60 mix with ¾ in. gravel
2. 1 : 1½ : 3/0·42 " " " "
3. 1 : 2½ : 5/0·65 " " ¾ in. granite
4. 1 : 2½ : 5/0·55 " " 1½ in. gravel
5. 1 : 2½ : 5/0·50 " " ¾ in. "
Batch fully mixed
Hand mixed
Standard Deviation
0·6
0·4
0·2
0
50
100
150
200
250
300
Mixing Time — Seconds

Fig. 10—The Within-Batch Variation of Sand/Cement Ratio with Mixing Time

THE TOTAL EFFECT ON THE QUALITY OF THE CONCRETE

In order to assess the total variation in the performance of the mixer it is necessary to consider not only the variation within one batch, but also the variation between batches. The results, therefore, were analysed statistically using the results of the five batches mixed for longer than the minimum time required for adequate mixing; the total standard deviation of the water/cement, sand/cement and aggregate/cement ratios after at least this minimum time (eighty-five seconds' mixing) are given in Fig. 12 for each

series of mixes and for the hand-mixed concrete.

The results of the analysis showed that generally the effect of the mix proportions on the total variation was similar to the effect on the variation within one batch, although there were some differences. The water/cement, sand/cement and gravel/cement ratios of the rich mix were all as uniform as those of the hand-mixed concrete, but when the mixer was used for a lean concrete there was an increase in the variability irrespective of the type of aggregate used (significant at the 1 per cent level for the water/cement ratio

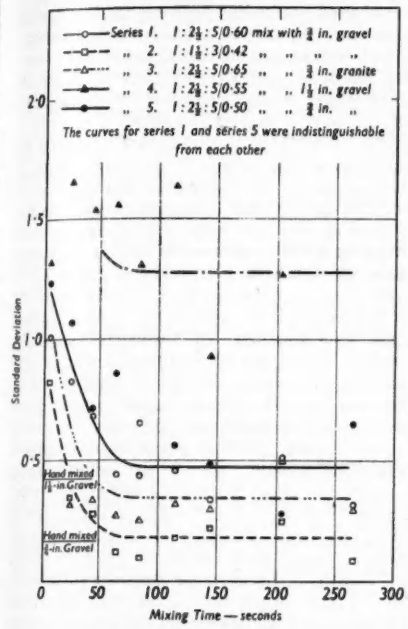
Series 1. 1 : 2½ : 5/0·60 mix with ¾ in. gravel
„ 2. 1 : 1½ : 3/0·42 „ „ „ „
„ 3. 1 : 2½ : 5/0·65 „ „ ¾ in. granite
„ 4. 1 : 2½ : 5/0·55 „ „ 1½ in. gravel
„ 5. 1 : 2½ : 5/0·50 „ „ ¾ in. „
The curves for series 1 and series 5 were indistinguishable from each other
Standard Deviation
2·0
1·5
1·0
0·5
Hand mixed 1½-in. Gravel
Hand mixed ¾-in. Gravel
0
50
100
150
200
250
300
Mixing Time — seconds

Fig. 11—The Within-Batch Variation of Coarse Aggregate/Cement Ratio with Mixing Time

and at the 0·1 per cent level for the sand/cement and aggregate/cement ratios). The average mix proportions determined by the analysis and the results of the analysis of variance are given in Table III. The small advantage within a batch shown by the sand/cement and aggregate/cement ratios of the concrete made with crushed granite was not maintained when the total variation in several batches was considered owing to the increased variability between batches ; the mixing efficiency in this case does not seem to have been affected by the type of aggregate.

In the same way as for a single batch there was no significant difference in the total variability of the water/cement ratio of hand-mixed concrete when 1½in gravel was used instead of ¾in, but the gravel/cement ratio was less uniform with the larger aggregate. The sand/cement ratio was also more variable for the hand-mixed concrete made with 1½in gravel, which seems to have been the cause of some increase in the batch-to-batch variation. This was probably due to the increased difficulty of mixing the materials dry when the large particles were present. In the same way, as already described when considering the variation within one batch, the water/cement and gravel/cement ratios of the concrete mixed in the machine with this large aggregate were much more variable than when mixed by hand when considering the total variation (significant at the 0·1 per cent level). There was, however, little difference between the uniformity of the sand/cement ratios and this was considered to be due to the large batch-to-batch variation of the hand-mixed material. In general the mix proportions had much less effect on the total variation of the sand/cement ratio.

The less workable mix showed a much greater total variation in the water/cement and gravel/cement ratios than was expected from the examination of the uniformity

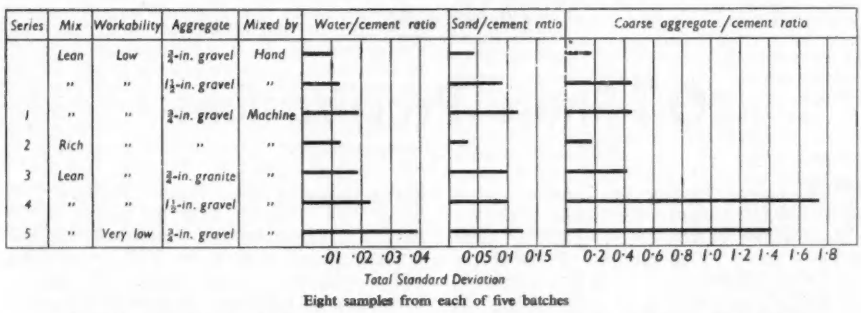
Series
Mix
Workability
Aggregate
Mixed by
Water/cement ratio
Sand/cement ratio
Coarse aggregate / cement ratio
Lean Low ¾-in. gravel Hand
„ „ 1½-in. gravel „
1 „ „ ¾-in. gravel Machine
2 Rich „ „ „
3 Lean „ ¾-in. granite „
4 „ „ 1½-in. gravel „
5 „ Very low ¾-in. gravel „
·01 ·02 ·03 ·04
0·05 0·1 0·15
0·2 0·4 0·6 0·8 1·0 1·2 1·4 1·6 1·8
Total Standard Deviation
Eight samples from each of five batches

Fig. 12—The Total Variation Between Samples After Mixing for the Minimum Mixing Time

within one batch. The water/cement ratio was, in fact, much less uniform than that of the mix containing 1½in aggregate (significant at the 0·1 per cent level), although there was little difference between the standard deviation within a batch for these two mixes. This increase in the total standard deviation of the dry mix can be accounted for by the considerable variation of the water/cement ratio between batches. The drier mix also resulted in a large increase in the standard deviation of the gravel/cement ratio, largely due to the variation between batches. With this type of mixer, when dry mixes are discharged there is generally a large amount of material left sticking to the drum, and the variation between batches was probably due to variations in the amount of material not discharged.

The opinion that much of the variability can be attributed to " sticking " in the mixer drum is supported by an examination of the average mix proportions determined from the samples. With one exception the water/cement and sand/cement ratios were very close to the designed values, but for all the batches from the mixer the aggregate/cement ratio was high. Further, the difference between the actual and theoretical value increased when the variability increased, which suggests that variation in the amount of material " sticking " in the drum is one of the chief causes of the lack of uniformity. It must be remembered that all these tests were made in a clean dry mixer, and that the average mix proportions would not be expected to be so different from the designed proportions after several batches had been mixed, but the presence of material sticking to the drum to which some of the batch may adhere or from which some material may be taken is bound to increase the variability.

The Effect of the Variations Due to the Mixer on the Design of the Mix

An estimate has been made of the effect of the variations caused by the mixer on the design of the mix. Using a river gravel and sand in the proportions of 2 to 1 and a water/cement ratio of 0·6, concrete of low workability would be obtained with mix proportions of 1 : 6·9.[3] With this mix the standard deviation of the water/cement ratio would be about 0·02, and we should expect that 95 per cent of samples would have a water/cement ratio of 0·6±0·04. It would be reasonable, therefore, to assume that the minimum strength of the concrete would correspond to a water/cement ratio of 0·64. If the methods of compaction were then altered so that a mix of " very low " workability could be substituted we should expect from normal mix design methods to be able to use a 1 : 8·6 mix with a consequent saving of about 17 per cent of the cement. The standard deviation of the water/cement ratio would, however, be increased to about 0·04 and we could only expect 95 per cent of samples to have a water/cement ratio within ±0·08 of the average. In order to produce concrete of the same minimum strength, therefore, the mean water/cement ratio would need to be 0·56 and the mix proportions 1 : 7·9, the saving in cement being reduced to 10 per cent. This estimate does not take into account the increase in cement content which would also be required to allow for the increased variation in workability caused by the increased variability of the gravel/cement ratio, and it is probable that the total saving in cement would only be about 5 per cent in

TABLE III—*The Average Mix Proportions and the Variance Within and Between Batches*

Series	Details of mix			Water/cement ratio			Sand/cement ratio			Aggregate/cement ratio		
					Standard deviation			Standard deviation			Standard deviation	
	Proportions	Compacting factor	Aggregate	Mean	Within batches	Between batches	Mean	Within batches	Between batches	Mean	Within batches	Between batches
Hand	1 : 2½ : 5/0·6	0·85	¾in gravel	0·604	0·0078	0·0084	2·48	0·038	0·025	5·06	0·168	Not significant
Hand	1 : 2½ : 5/0·55	0·85	1½in gravel	0·543	0·0077	0·0106	2·49	0·047	0·099	4·97	0·426	0·202
1	1 : 2½ : 5/0·6	0·85	¾in gravel	0·603	0·0118	0·0167	2·55	0·046	0·101	6·75	0·475	Not significant
2	1 : 1½ : 3/0·42	0·85	¾in gravel	0·425	0·0082	0·0107	1·57	0·023	0·026	3·76	0·178	Not significant
3	1 : 2½ : 5/0·65	0·85	¾in granite	0·600	0·0113	0·0167	2·42	0·031	0·103	5·67	0·343	0·257
4	1 : 2½ : 5/0·55	0·85	1½in gravel	0·542	0·0186	0·0161	2·47	0·089	0·046	7·61	1·768	Not significant
5	1 : 2½ : 5/0·5	0·76	¾in gravel	0·498	0·0175	0·0381	2·35	0·095	0·087	7·85	0·498	1·446

All figures were calculated from the analysis of eight samples from each of five batches.

practice. The economy to be expected from the use of lean dry concretes will only be fully achieved when methods of mixing these concretes are improved.

Conclusions

The tests have shown that although variations in the mix proportions did not affect the time required for adequate mixing, they had a considerable effect on the quality of the concrete produced. A rich mix of low workability was mixed as uniformly in the small, non-tilting mixer as concrete could be mixed by hand, but a lean mix was less well mixed. The use of aggregate of a larger maximum size or of a drier and less workable mix, resulted in a further increase in variability. Modern specifications which call for the use of lean dry concrete with large sizes of aggregate do, therefore, give rise to more difficulty in obtaining a uniform mix.

The economy which can be achieved by the use of these lean dry concretes in practice is therefore considerably less than expected from laboratory tests, owing to the increased variability of the material, and it is desirable that methods of mixing these concretes should be improved.

Acknowledgments

The work described in this article was carried out as part of the programme of the Road Research Board of the Department of Scientific and Industrial Research. The article is published by permission of the Director of Road Research.

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(To be continued)

Off-Shore Procurement

(By our American Correspondent)

THE recent signing in London of a 90,000,000 dollar contract under which the United States purchased 500 British "Centurion" tanks, to be supplied to the Dutch and Danish contingents of the NATO forces, has led to much discussion of the effects the American off-shore procurement programme is having on the defence industries of the United States. An off-shore purchase, as its name implies, is the buying of goods from countries other than the United States with dollars supplied by the United States. It is not a new method, and it was first employed under the Marshall Plan to convert the bilateral American dollar aid into a multilateral system of dollar payments. It is only recently, however, that the off-shore procurement system has shown promise of becoming a major tool of American foreign policy. Its potentialities for revitalising European industry, reviving international banking, even on a limited scale, and saving money for the American taxpayer, are considerable. Although admitting that the system still involves certain difficulties in the fields of patent rights, engineering standards and specifications, cartel limitations and foreign tax laws, its advocates in America claim that it will provide sources of military equipment in Western Europe where the brunt of any Communist aggression would be first felt; lay the groundwork for a greater European self-sufficiency in military production; expedite deliveries of essential equipment; relieve the strains on American industrial capacity and the drain on raw materials provided by the United States; provide dollar savings due to the cost differentials in defence production between Europe and the United States; and contribute in a limited degree to the economies of these European countries by providing them with additional sources of United States dollars.

Although these foreign contracts for military equipment will remain small compared with the increasing flow of weapons made in the United States, they have already taken on a psychological importance much greater than their mere monetary value and have opened up many fields of industrial activity. The story is told of an Italian manufacturer who, recently, visited the director of the U.S. Army Office of Military Assistance and talked with a smile about returning good times. He now employs 3000 workers with the aid of a 60 million dollar ammunition contract from the United States, where he had fewer than 100 employees two years ago. The Italian manufacturer talked about building an explosives works and the American director of foreign contracting wanted to know what he proposed to use for money. Promptly, the manufacturer replied that there was plenty of money to be had in Italy provided he could produce a United States war contract. The traditional relation between necessity and invention was rather well demonstrated in the case of contracts placed some time ago in France for the production of military vehicles. For lack of orders, two of the larger automotive factories had planned to curtail operations. The implication of this prospect on the resurgent French Communists was enough to give the American State Department a bad case of jitters, until the American Special Representative in Paris suggested that a part of the orders held by overloaded United States plants could be supplied by French factories. But the United States could not provide dollars for the vehicles until they were delivered, no matter how badly they were needed by the French Government to avert a Parliamentary crisis growing out of a budget deficit. The Export-Import Bank in New York came to the rescue and advanced the funds required. As a result, at least 4000 French workers were saved from dismissal and have had steady employment ever since. The mechanics of off-shore purchasing have been improved considerably since those days, and depending on the extent to which raw materials have been acquired by the contractor and committed to processing operations, the American Government now has authority to effect prepayment of contracts up to 70 per cent of their face amount. Even to-day, however, it is not always easy to convince Washington of the quality of foreign designs and methods of production. Thus, a lot of work had gone into contending, for the benefit of European military staffs, that the "Centurion" tanks were greatly inferior to the comparable American-made weapon. But a difference in cost of 75,000 dollars in favour of the "Centurion," accompanied by an excellent combat record obtained in the Korean fighting, apparently helped to change a lot of minds.

Although some American authorities are inclined to question whether foreign contracting for military equipment can effectively take the place of economic aid grants in keeping Europe on its feet, others contend that the possibilities of the system are limited only by the need to maintain an adequate production base at home. From the point of view of competition from domestic manufacturers, it has been relatively easy so far to get orders into the hands of factories abroad. However, it will be a different story when the peak of defence spending in the United States has been reached and when idle plant capacity at home becomes a political as well as an economic problem. There has been enough experience with so-called "distressed areas" of defence production in the past to suggest the howls that will go up in Congress if foreign manufacturers continue to make things for Uncle Sam at such a time. It mattered little to certain interests in the past that such distress unemployment in American industrial centres could be attributed only to steel strikes and material shortages. It was all too easy to make it appear that foreigners were profiting at the expense of Americans. This, rather than any shortage of industrial capacity abroad, may prove to be the effective ceiling on such purchases of military equipment in Western Europe. There are, of course, more valid and reasonable objections now being raised against off-shore procurement on too ambitious a scale. One is the definite need of any country to maintain an adequate production base at home. And, to the military mind, at least, nothing is more desirable than a going manufacturing concern with a "healthy" backlog of defence orders to fill. Yet it is to be hoped that the new American Administration will bear in mind the most convincing argument in favour of off-shore purchasing: that it facilitates badly-needed military equipment to be supplied to the member countries of NATO at comparatively lower cost and, at the same time, that in line with the "trade, not aid" principle, it enables these countries to earn dollars, instead of relying on the charity of the American taxpayer.

American Engineering News

(By Our American Correspondent)

Progress of the Tennessee Valley Authority

The 19th annual report to Congress of the T.V.A., which was recently published, emphasises that the Tennessee Valley area is being transformed from a predominantly agricultural to an important and rapidly expanding industrial region. Industry has expanded more rapidly in the Tennessee Valley region than in the United States as a whole, although the expansion of industrial employment has not been rapid enough to use the manpower available in the district. The growth of industry is beginning to bring about a healthier balance with agriculture; however, one of the primary requirements of the region which must be met is the continued growth of power generating capacity to meet electricity requirements as they arise. It is reported that construction is proceeding to increase the installed capacity of the power system from 3860MW at the end of the last fiscal year to 9600MW by January, 1956. The greatest single factor in the rapid increase in demand for power in the region is the U.S. Atomic Energy Commission, with its large expansions at Oak Ridge, Tennessee, and a new plant being built at Paducah, Kentucky. It is expected that the total amount of power produced by T.V.A. to be used by the Atomic Energy Commission will be eventually 24,000 million kWh a year. By 1956 the total power demands of

the region will be 59,000 million kWh, compared with 23,000 million kWh in the 1952 fiscal year and 12,600 million kWh in 1954.

Construction was carried on at a high rate during the past year on five steam-electric generating plants, two dams, and new generating units at seven existing dams. Shortly after the close of the fiscal year the Congress authorised schemes for two additional steam power stations, bringing the total under construction now to seven. The generating capacity of the T.V.A. system was increased by 678·8MW during the year, two-thirds of it being accounted for by the initial operation of the first four 112·5MW generating units at the Johnsonville steam power station, which will have six units when completed. New turbo-generators of 24·3MW and 27MW capacity respectively were placed in operation at the Guntersville and Chickamauga dams, and four 25MW units were placed in operation at the Wolf Creek dam of the U.S. Army Corps of Engineers on the Cumberland River system. This is one of several U.S. Army dams from which the T.V.A. purchases power for distribution over its own system. The Boone dam on the South Holston River is now approaching completion. It will be 140ft. high and 1330ft long and will provide 163,500 acre-feet of useful storage for flood control and maintenance of flows for power production and navigation. The concrete gravity dam structure has earth embankments, and the scheme as a whole is expected to involve placement of 191,000 cubic yards of concrete and 530,000 cubic yards of earth and rock fill. The power station of the dam has been designed for the ultimate installation of three 25MW turbo-generators. The Fort Patrick Henry dam, situated on the same river, was still in a very early stage of construction at the end of the fiscal year.

The net revenue from the power operations of the system during the last year amounted to 25,839,000 dollars, representing a return of 4·7 per cent on the net average investment in power generating facilities. Over the nineteen years of its operations the average annual return has been 4·3 per cent. The use of electricity has continued to grow in the T.V.A. region. The average residential consumer in the area used 3907kWh during the past year, compared with the national American average of 2091kWh per customer. The average cost per kilowatt-hour for residential service was 1·35 cents—less than half the national average cost of 2·78 cents per kilowatt-hour. Twenty thousand new farm consumers received service during the year, so that about séven out of eight farms in the valley now have electricity compared with one out of twenty-eight in 1933.

During the past year the system of river dams was used to lower the crest of a flood on the Lower Ohio River by 6in, a reduction which averted an estimated 400,000 dollars damage. This has brought the total estimated flood damage averted since the first T.V.A. project went into operation to 51,266,000 dollars, whereas the cumulative flood control costs have been only 22,200,000 dollars. During a long period of high flows on the Ohio River the T.V.A. system was operated to give protection to the cofferdam at the site of the steam power station being built by Electric Energy, Incorporated, which will supply part of the power for the Paducah plant of the Atomic Energy Commission. As a result of navigational improvements of the Tennessee River channel river traffic amounted to 525 million ton-miles during the calendar year 1951, compared with 30,000,000 ton-miles in 1933 and 230 million ton-miles in 1945. For the third successive year a survey disclosed no evidence of locally transmitted malaria in areas along the T.V.A. lakes. In 1934 a survey along the river in Northern Alabama had shown 28 per cent of the population to have been infected. In the field of chemical engineering activity works of the T.V.A. produced about 340,000 tons of phosphate and nitrogen fertilisers during the past fiscal year. This, however, constitutes only about 4 per cent of the total supply of nitrogen and phosphate fertiliser in the United States. In view of the fact that more phosphates are needed to balance the increased production of nitrogenous fertilisers since the war, the Authority has emphasised research into nitric phosphate processes, using nitric acid for treatment of phosphate rock rather than sulphuric acid, which is now in short supply in America. Several processes have been carried through pilot plant stages of research, and one of them is to be used in a new production plant to be built by a co-operative organisation.

The Schiller Power Station at Portsmouth, New Hampshire

Interesting results have been obtained at the Schiller power station of the Public Service Company, of New Hampshire, at Portsmouth, New Hampshire, during the first two years of its continuous operation. A detailed description of the power plant installation, which is based on the binary-vapour cycle, was published in THE ENGINEER of June 15, 1951, page 789. The installation comprises two 7·5MW mercury units of standardised design and one 25MW steam turbo-generator set, co-ordinated in design and rating to constitute a power generating unit having a rated capacity of 40MW. Each of the two mercury boilers is capable of generating 987,000 lb per hour of mercury vapour, which enters the mercury turbines in the dry, saturated state, at an absolute pressure of 128 lb per square inch and at a temperature of 962 deg. Fah. After leaving the turbines at an absolute pressure of 2·53 lb per square inch and a temperature of 528 deg. Fah., the mercury vapour enters the mercury-condenser steam boilers, where, in giving up its latent heat, it generates steam at a temperature of 496 deg. Fah. and a pressure of 643 lb per square inch. The liquid mercury is fed back to the mercury boilers by two 200 h.p. feed pumps, and the steam is passed through two superheaters situated at the top of the mercury boilers. The superheated steam enters the steam turbine at the rate of 248,700 lb per hour and at a total temperature of 825 deg. Fah. and a pressure of 600 lb per square inch. The steam turbine exhausts into a surface condenser maintained at a temperature of 79 deg. Fah. and an absolute pressure of approximately 0·5 lb per square inch. Finally, the steam condensate is pumped back to the mercury condenser steam boiler.

After certain initial minor plant adjustments and changes, the station went into regular operation in July, 1950, at an average load of 46MW. Except for two inspection shutdown periods, the power plant was run at this load until October 15, 1950, when vibration was noticed in the steam turbine. This did not appear excessive, but was considered sufficient to warrant an investigation. As the steam unit was coming to rest it was obvious that the situation was critical, and on lifting the turbine casing it was found that four buckets in the blading of the fourteenth stage had failed. The approaching Christmas peak made it desirable to get the plant back into operation as soon as possible ; therefore the fourteenth stage buckets were completely removed and the turbine closed up. The station was again in service by November 1st, carrying a load of 43MW until the end of February, 1951, when conditions permitted the plant to be shut down for an annual overhaul and to have the fourteenth stage blading replaced. In early operations it appeared that the deposit of solids in the steam circulating system was excessive. These accumulated in the steam superheater tubes and on the steam turbine buckets. During the overhaul period in March, 1951, the superheater tubes were thoroughly acid cleaned. This cleaning, together with modifications in the feed water treatment, has relieved this problem to some degree. At present the station is being operated at a base load of 46MW.

While the makers of the plant guaranteed a thermal efficiency of the integral mercury-steam unit of 9211 B.Th.U. per net kilowatt-hour at a design load of 43·17MW and when burning oil fuel, a recent twenty-four-hour test showed the station to have an actual efficiency under these conditions of 9133·7 B.Th.U. per net kilowatt-hour. This performance test was conducted in such a manner as to test the entire plant as a unit. Load was set at the design rating of 43·17MW and held for twenty-four hours. All other items, such as voltage, power factor, back pressure on the steam unit, &c., were held to design values with a tolerance of ±1 per cent. The fuel oil was very carefully weighed and the electrical output measured on calibrated meters. The calorific value of the fuel oil was determined from a composite sample taken hourly during the run.

An additional 40MW turbo-generator unit, employing a conventional steam cycle, went into regular service at the power station in October, 1952. A second, similar addition is scheduled to begin operation in the summer of 1955.

Reversible Pump-Turbine Unit for the T.V.A.

A contract to supply a reversible pump-turbine unit for installation as part of a pumped storage scheme at the Hiwassee dam of the Tennessee Valley Authority in South-Western North Carolina has been received by the Allis-Chalmers Manufacturing Company, of Milwaukee, Wisconsin. This project is of particular interest as there have so far been only very few pumped storage schemes in the United States and, furthermore, because the pump-turbine unit is claimed to include the largest Francis runner ever built and the largest electric motor in the world. The Hiwassee dam on the Hiwassee River is a concrete gravity dam having an overall length of 1287ft, a maximum height of 307ft and a maximum base width of 493ft, including an integral apron. The spillway has a width of 260ft and comprises seven radial gates, each 23ft high and 32ft wide. The reservoir has a shore line of 180 miles and a storage capacity of 438,000 acre-feet. Construction of the dam was started in 1936 and completed in 1940. The Hiwassee power station was designed for an ultimate installation of two turbo-generator units. Only one 57·6MW vertical Francis unit has so far been installed, and the vacant stall is now being adapted to receive the new Allis-Chalmers reversible unit. When operating as a turbo-generator the turbine will have a maximum rating of 120,000 h.p., with the generator being rated 70,000kVA at 13·8kV. When operating as a motor-driven pump unit the pump will have a rating of 3900 cusecs against a head of 205ft, with the motor being rated 102,000 h.p. at 106 r.p.m. As a pump the unit has considerably more capacity than each of those serving the Grand Coulee dam irrigation project, which are at present considered to be the largest pumps in the world and have a maximum capacity of 1600 cusecs at a 280ft head (THE ENGINEER, September 21, 1951, page 354). In a normal cycle of operation the pump will begin lifting water from Apalachia Lake into Hiwassee Lake under a head of 135ft at 5200 cusecs. By the time the upper reservoir is filled the head will have increased to 254·5ft. At the beginning of operation as a turbine the unit will generate at the rate of 120,000 h.p. and drop to 36,000 h.p. as the reservoir approaches the low point. The guaranteed efficiencies of the unit are 90 per cent as a pump and 89·5 per cent as a turbine. Investigation has shown the application of this reversible unit to be economically feasible and profitable because the off-peak power for pumping will cost less and improve the load factor on the system, while the power generated for peak loads will result in additional revenue. The installation is scheduled for completion in 1955.

ALUMINIUM BROCHURE.—We have received from T.I. Aluminium, Ltd., Tyseley, Birmingham, a booklet with the title "Materials and Fabrication," and the first of a series dealing with the products of the company. There is a summary of T.I. Aluminium alloys which are divided into eight groups and this is followed by heat-treatment information. A series of tabular statements are given which list the company's alloy numbers and their related British Specifications, together with the mechanical properties and chemical composition of each alloy for sheet, sections, tubes and plate. Sections of the booklet deal generally with machining, forming, welding, riveting and surface treatment and finishing, while a final note deals with the question of supply.

RELAXATION METHODS.—An Easter school on "Relaxation Methods" is to be held at the Imperial College of Science and Technology, South Kensington, S.W.7, from April 9th to 23rd. The course will cover the numerical solution of linear algebraic equations, framework problems, Laplace's and Poisson's equations, the biharmonic equation, eigen value problems, the heat-conduction equation, three-dimensional relaxation, &c. There will be daily lectures at 10.15 a.m. and 11.30 a.m., with numerous examples to be solved under supervision in the afternoons. The fee for the course will be £10, payable to the Imperial College. The College may be able to provide accommodation in the hostel building, the daily charge for a room being 9s. Meals are obtainable in the College Refectory. Applications should be addressed to Mr. D. N. de G. Allen, Imperial College, London, S.W.7.

Fuel Cells

Renewed interest is being shown in the possibilities of developing fuel cells for the generation of electrical energy. The following paragraphs are abstracted from a report, "Fuel Cells: A Non-Technical Outline of Their Development," by Mr. A. P. Paton, published by the British Electrical and Allied Industries Research Association, Thorncroft Manor, Dorking Road.

MANY types of cell have been studied, but, except for one or two of the examples discussed below, their characteristics suggest that they could never run economically on a large scale. A direct cell, in which some form of solid carbon could be used as the anode, has obvious potential advantages; in practice, however, indirect cells, using hydrogen or carbon monoxide as fuel, have proved more successful.

The Hydrogen-Oxygen Cell

As early as 1839 Sir William Grove was able to demonstrate that, using dilute sulphuric acid as electrolyte and electrodes of activated platinum, hydrogen and oxygen would react to yield a small electric current. In 1889, a similar cell was developed by Mond and Langer and, although a current density of 6A per square foot of electrode was achieved, at an efficiency of nearly 50 per cent, further progress was prevented because the platinum electrodes used were too expensive. The concentration polarisation* in this cell was very pronounced and, in order to maintain efficiency, the cell was depolarised at regular intervals by interchanging the streams of gas and thus altering the direction of the current.

In the year 1932, after an exhaustive study of the literature relating to fuel cells, F. T. Bacon decided that the hydrogen-oxygen system showed the most promise. Since the time of Mond and Langer the metallurgical industries had made considerable progress and many new metals and alloys, which could be obtained at reasonable prices, provided alternatives for the electrode material. Using electrodes of pure nickel, F. T. Bacon has made substantial progress with this system, and is at the present time continuing the research under the direction of Professor T. R. C. Fox at Cambridge, the programme being sponsored by the Electrical Research Association and the Ministry of Fuel and Power.

The cell at present in use at Cambridge consists of two porous nickel electrodes between which potassium hydroxide is circulated. The reacting gases, hydrogen and oxygen, are fed into the cell from opposite sides and an e.m.f. is generated between the two electrodes. The performance of the cell can be improved considerably by increasing the working temperature and pressure. By the end of 1950 a cell had been constructed which would operate at 300A per square foot at 0·79V. This represented an efficiency of 60 to 65 per cent calculated from the free energy of the reaction and was attained by raising the operating temperatures to 200 deg. Cent. and the pressure to 600 lb per square inch. The length of run was, however, severely limited by deterioration of the oxygen electrode after which the efficiency of the system fell off rapidly. Davtyan in 1947 published details of work carried out at the Academy of Science in Moscow, in which he claimed that, if the electrodes were made of activated carbon impregnated with various metals, an efficient hydrogen-oxygen cell could be produced which would work at room temperature. In view of the promising results published by Davtyan, the Electricity Supply Research Council initiated a research on this type of cell, the work being done by the British Electricity Authority under the direction of Dr. J. S. Forrest. The experiments so far completed have not been very encouraging, but an exhaustive examination of cells of the Davtyan type has not yet been made.

High-Temperature Indirect Cells

Promising results with cells of this type were obtained in Germany some thirty years ago, notably by Baur and his collaborators using hydrogen or carbon monoxide and air with molten salt electrolytes.

The Greger Cell.—In 1932 patents were taken out in Great Britain and America by Dr. H. Greger for a fuel cell which was said to work very satisfactorily using hydrogen, carbon monoxide or methane and oxygen. The electrolyte used was a complex mixture of carbonates and chlorides of sodium potassium and barium, which melted at 600 deg. Cent. No information has been given concerning this system since 1938, when successful laboratory tests had encouraged the sponsors to the extent that they were considering the development of this cell on a large scale.

The Gorin Cell.—Quite recently there has been a new development in U.S.A. details of which are given in U.S.A. Patents 2,581,650/1, granted to Dr. E. Gorin, of Pittsburg Consolidated Coal Company, and referred to in *Electrical World*, 137, 24 (June 23, 1952). Highly reactive carbon is converted into water gas which is subsequently oxidised in the presence of solid electrodes and electrolyte to produce electricity as in the high-temperature cell developed by Davtyan. The patent itself deals with a method of using the heat produced in the fuel cell to preheat the air/steam mixture supplied to the gas generator. The article mentions that Government power experts are enthusiastic about the ultimate possibilities in, say, five or ten years' time. Efficiencies as high as 75 per cent are claimed, but so far the operating life is short.

Redox Cells

Research has been carried out by Dr. A. M. Posner at King's College, London, under the direction of Professor Sir Eric Rideal, on a fuel cell involving Redox processes. In this type of cell the anolyte and catholyte act as electron carriers and must be separated by some form of diaphragm. The electrolytes are regenerated by direct interaction of the anolyte with air and the catholyte with carbon. Various cells have been tested and some interesting results have been obtained. There is still a considerable amount of work to be done on the mechanism involved in the regeneration of the catholyte and on the conditions necessary to obtain maximum activity of the carbon. Similarly, suitable catalysts are needed for accelerating the regeneration of the anolyte. The cell itself has not been as efficient as was originally expected, and it will be some time before any decision can be made regarding the possible use of a fuel cell involving Redox processes.

High-Temperature Direct Cells

No summary of the development of fuel cells would be complete without mention of the attempts which have been made to build a cell in which a carbon anode could be oxidised electrochemically to produce an electric current. At room temperature carbon is very inert and cannot be ionised; thus, in order to promote the anode reaction, the cell must run at quite a high temperature. With electrolytes made from fused salts many difficulties are encountered, amongst which the most important are probably the corrosion due to the electrolyte and the volatilisation of the electrolyte. Cells have been constructed with a solid conducting diaphragm separating the anode and the cathode instead of a molten electrolyte, but these cells polarise rather badly. Baur (1941) claimed some success with high-temperature direct cells, but it is very unlikely that this type of cell could be used on a commercial scale.

Future Developments

If a practical fuel cell is produced it will have to compete with several well-established processes by which electrical energy can be generated. If the high efficiencies which have been obtained in laboratory tests could be produced on an industrial scale, and furthermore, if they could be maintained over long periods of time, then the fuel cell would immediately become a worthwhile practical proposition.

Modern techniques are already helping us to get a clearer picture of the basic principles involved, and there are reasonable grounds for the belief that a satisfactory fuel cell can be constructed on a laboratory scale. Design of an economical commercial prototype is another matter and is likely to require considerable technical and material resources.

The possibility of using, say, a hydrogen-oxygen cell as a means of storing electrical energy, e.g. in conjunction with generators driven by wind power, should not be overlooked, since the incremental cost of kilowatt-hour for a given kilowatt output could probably be kept much lower. A battery of such cells would probably have a much higher power-to-weight ratio than that of the lead accumulator and might also be developed for traction purposes.

A fuel cell would have to be more than 40 per cent efficient to compete economically with combustion methods for producing electrical energy and it must also use fuels which are readily available without expensive processing. Although the energy is produced as low-voltage direct current which is not convenient for transmission of large quantities of power, it is suitable for use in electrochemical processes, such as the electrolytic extraction of metals like aluminium and magnesium which are large consumers of electrical energy.

* A voltage drop due to changes in the uniformity of concentration of the electrolyte during operation of the cell.

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Indian Paint Industry

THE Indian paint industry was established in Calcutta, West Bengal, in 1902, and the pioneering firm, the Shalimar Paint, Colour and Varnish Company, which led the field with the opening of its first factory in that year, has just celebrated its golden jubilee. The industry, which now produces enamels, lacquers and pigments, besides paints and varnishes, has over fifty factories, of which fifteen are large and well-established. It has increased its production capacity from almost nil to about 65,000 tons of paints and enamels, 2·5 million gallons of varnishes, and just under 10,000 tons of other products, including zinc oxide, lead pigments and aluminium powder. The value of products manufactured in the year 1950/51 was Rs. 5·96 crores (£4·5 million).

The industry's post-war progress has kept pace with that in other industries, but the lack of a sufficiently well-established organic chemical industry has proved a rather unfortunate handicap. The country produces most of the raw materials needed in the manufacture of paints, such as linseed oil and castor oil. Of late, experiments have been proceeding at the newly-established National Chemical Laboratory with a view to exploring the possibilities of using other native substitutes, such as "alma" oil, tobacco seed and walnut oil. It is reported that the experiments are promising on a pilot scale.

The Paints and Varnishes Panel, appointed by the Government of India, has recommended the setting-up of a central paint laboratory, in consultation with the industry. The Panel has also suggested that the laboratory should act as a training centre. So far, none of the recommendations have been implemented, but the final report of the Five Year Plan has set some ambitious targets. The target fixed for paints and enamels is 100,000 tons, as against the current output of 65,000 tons, and 300,000 gallons for superior quality varnishes, compared with the present level of about 140,000 gallons.

Measurement of Blade-Tip Clearances in Aircraft Turbines*

By I. A. MOSSOP, B.Sc. Tech., and F. D. GILL, B.Sc. (Eng.)†

An instrument has been developed for use by airfield maintenance personnel in the checking of turbine-blade clearances, both in turbo-jet and turbo-prop engines. The measurements are made by plugging a cable into various capacitance pick-up points around the shroud ring and spinning the rotor, either by hand cranking or by the starter motor.

IN turbine engines it has been necessary to check, at regular intervals, the clearances between the blade tips and the shroud ring, to ensure that safe working clearances are being maintained, despite growth of the blades and any distortion of the shroud ring that might occur in service. Improved materials and design technique have reduced the frequency of inspection required, and recently the stage has been reached when it seems likely that regular inspection can be dispensed with completely.

Although the instrument described in the paper may no longer be required for its original purpose, the underlying measuring technique may have many other applications, especially to those problems which can be resolved in to the measurement of a minute change of capacitance to earth at the far end of a long cable.

The instrument works on a capacitance principle, but the measurement does not depend for its accuracy on the similarity between the pick-ups ; balancing, calibration and—ultimately—measurement at a pick-up point are possible without moving the attachment cable, except when changing to the next pick-up. Clearances are indicated on a peak voltmeter, scaled to show the clearance being measured as a fraction of the value to which the instrument has been calibrated. The instrument selects the longest blade and measures its clearance.

The instrument has several novel features. The use of a transformer, placed part-way along the pick-up lead and designed to make the whole

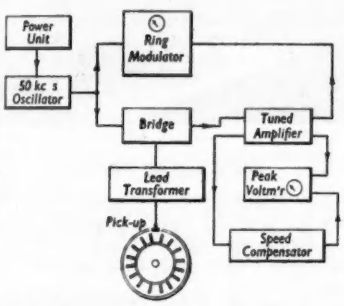


Fig. 1—Block Diagram of Turbine Blade Clearance-Measuring Instrument

lead parallel-resonant, not only makes possible the measurement of minute capacitance changes at the end of a long cable but enables a simple resistance bridge to be used for this measurement. This bridge is fed by a stable crystal-controlled 50 kc/s oscillator. With the present equipment it is possible to detect capacitance changes of approximately 0·003 $\mu\mu$F at the end of a cable 23ft long, requiring an overall capacitance sensitivity, $\delta C/C$, of 10^{-5}.

The method of calibrating the instrument results in the greatest accuracy of measurement for clearances near the calibration value, the estimated error being less than ± 5 per cent.

Principle of Operation.—The block diagram of Fig. 1 shows the essential components of the instrument. [A complete circuit diagram and a detailed description of the circuit is given in the paper.]

For any given engine the capacitance between the pick-up and the blade tip is dependent on the clearance between them. Any difference between the capacitance corresponding to an actual blade clearance and that of a reference value used to calibrate the instrument unbalances an a.c.-fed bridge, and after amplification the out-of-balance voltage is rectified and indicated on a peak voltmeter. When several blades are moved in succession across the face of the pick-up, as when the rotor is turned, the indication on the peak voltmeter is a measure of the smallest clearance amongst them. The meter has a single hyperbolic scale and indicates the clearance being measured as a fraction of the value to which the instrument has been calibrated.

No attempt has been made to show which blade is the longest ; in the present application this is unnecessary, as a turbine is considered defective when the clearance of any one blade is less than the safe value.

Capacitance Pick-up.—A capacitance pick-up is shown in Fig. 2. The shell and centre rod are of stainless steel whilst the insulator is ceramic. The insulator is silvered on the inner and outer faces to short circuit the unpredictable air capacitances formed between the ceramic and

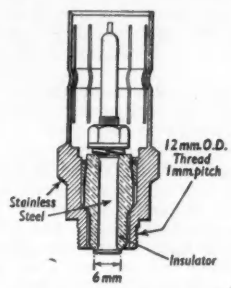


Fig. 2—Capacitance Pick-up

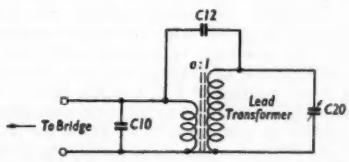
the metal. The capacitance between the shell and the inner electrode is approximately 9 $\mu\mu$F, but small variations in the self-capacitance between different pick-ups are of no consequence, since they are taken up in the variable capacitor on the lead transformer in the course of initial balancing.

Lead Transformer.—The lead transformer is so mounted within the aluminium box as to minimise earth capacitance. A variable capacitor connected across the lead to the pick-up gives capacitance adjustment for initial bridge balancing.

The toroidal dust cores, having a permeability 50, are wound in 22·5 deg. sections to keep the self-capacitance of the winding to a minimum. A typical transformer, having a 300-turn primary and a 1200-turn secondary, both wound with 33 S.W.G. wire, has a measured total self-capacitance of approximately 7·8 $\mu\mu$F, and a calculated lumped capacitance between primary and secondary of approximately 7·7 $\mu\mu$F.

Such a transformer has a Q-factor between 100 and 150 at 50 kc/s.

Bridge and External Bridge-Arm.—The bridge is a simple four-arm resistance bridge with two arms fixed, the third variable and the fourth the resonant circuit formed by the pick-up, lead and transformer, which at parallel resonance is a pure resistance. It is sometimes called a



C10 = Combined capacitance of lead from bridge and transformer primary.
C12 = Inter-winding capacitance.
C20 = Combined capacitance of transformer secondary, lead and pick-up and variable pick-up capacitance.

Fig. 3—Circuit of External Bridge Arm

resonance bridge. The values of the resistors have been chosen so that the four arms, the source and the detector have nearly equal impedances, in this case approximately 100 kilohms.

The bridge output is transformer-coupled to the amplifier, so that it is possible to earth both oscillator and amplifier, as well as one side of the pick-up. The transformer is air-cored and is wound on concentric bobbins in such a way that stray capacitances introduced into the bridge by the transformer are symmetrical about the earth point and hence do not affect the conditions for balance. Wire-wound resistors, fixed and variable, have been used throughout the bridge, to ensure high stability.

The circuit of the external bridge-arm (consisting of the lead transformer with its input and output leads) and pick-up is shown in Fig. 3,

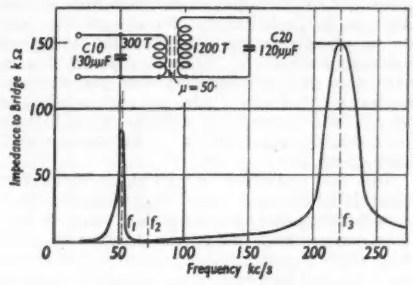


Fig. 4—Impedance/Frequency Characteristic of Typical External Bridge Arm

and the measured impedance/frequency characteristic for a typical external bridge-arm is given in Fig. 4. It will be seen that the circuit is parallel-resonant at two frequencies, f_1 and f_3, and series-resonant at f_2, and that the impedance of the circuit changes very rapidly with small increases of frequency above f_1. A similar result would be obtained if, at a constant supply frequency equal to f_1, an element of the circuit were changed. It should be noted also, that at the parallel-resonant frequency f_1, the impedance of the circuit is purely resistive and so can be balanced on a resistance bridge.

If the inter-winding capacitance is sufficiently small to be neglected in comparison with the capacitances across the primary and secondary windings, the equivalent circuit of the complete external bridge-arm can be simplified to that shown in Fig. 5(*a*). The parallel circuit ABC can be replaced by an equivalent series circuit

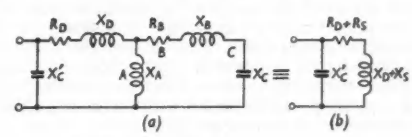


Fig. 5—Equivalent Circuits of External Bridge Arm

which is inductive at frequencies below the resonant frequency of circuit ABC and is capacitive at frequencies in excess of the resonant frequency. The external bridge-arm operates at a frequency f_1 (Fig. 4) which is below the individual parallel-resonant frequency of circuit ABC. The equivalent circuit can thus be reduced to a single parallel circuit, as shown in Fig. 5(*b*).

If the circuit of Fig. 5(*b*) is in parallel resonance, small changes in either of its arms will produce considerably larger proportional changes in the total impedance. If, at the same time, circuit ABC of Fig. 5(*a*) is also nearly in parallel resonance, large changes in its equivalent series impedance will result from small changes in either of its constituent arms. Since these two effects act in cascade, the impedance of the complete circuit at parallel resonance is extremely sensitive to small changes in the secondary circuit ABC.

The secondary circuit ABC can be designed to have a high Q-factor, but the effective series resistance R_S, which increases as circuit ABC approaches parallel resonance, limits the Q-factor of the main parallel circuit (Fig. 5(*b*)) to a lower value. The total impedance of the circuit is thus sensitive to changes in the secondary circuit ABC, such as for example to X_C, and relatively insensitive to changes in the primary circuit, such as to X'_C. The pick-up capacitance controls the value of X_C whilst X'_C is due almost entirely to the capacitance of the cable on the bridge side of the lead transformer.

The amplifier is conventional. The output from the amplifier is transformer-coupled to

* Abstract, Institution of Electrical Engineers, Measurements Section Paper, February 17, 1953.
† Royal Aircraft Establishment.

the peak voltmeter, which consists of a capacitor charged through a diode. The voltage across this capacitor is measured by a high-input-impedance cathode-follower stage. The meter in the cathode lead of this valve has a conventional 0–150V, 1mA moving-coil movement.

Gap Balance Detector.—At balance the bridge is phase-sensitive in the sense that an increase of pick-up capacitance produces an out-of-balance voltage differing in phase by 180 deg. from that which would be obtained for a similar decrease of capacitance. To obviate the need for a phase-sensitive amplifier, the bridge is balanced normally for minimum capacitance, i.e. with the pick-up opposite the gap between blades, so that any blade, no matter what its length, will produce a bridge out-of-balance voltage in the same sense when it passes beneath the pick-up.

The first operation in setting-up the instrument is to balance the bridge with the rotor in whatever position it may have come to rest. This may or may not be the position of minimum pick-up capacitance, and in an actual engine the rotor and pick-up are not visually accessible, so that a manual adjustment of their relative positions is not possible.

Use has been made of the phase-sensitivity of the bridge in devising a circuit, the gap balance detector, to overcome the above difficulty.

Speed Compensator.—When the turbine rotor is spinning at a constant speed and the meter reading has reached an equilibrium value, the rise in voltage across the peak voltmeter capacitor during the charging time, i.e. when a blade is passing the pick-up, is equal to the fall in voltage during the discharge time when no blade is present. The magnitude of these voltage fluctuations is dependent on the rotor speed, a reduction in speed increasing the amplitude and vice versa. If, owing to the passage of a blade under the pick-up, the signal to the peak voltmeter were rectangular in wave-form, then at all times, irrespective of rotor speed and hence amplitude of the above-mentioned voltage fluctuations, the ratio between charge time and discharge time of the peak voltmeter capacitor would be constant for a given rotor assembly. Since, however, in practice the signal is not rectangular but at every point has finite slope, the ratio of charge time to discharge time of the peak voltmeter capacitor is reduced by a decrease in amplitude of the voltage fluctuations caused by an increase in rotor speed. The net effect of this is to cause the meter reading for any given clearance to fall with increasing speed of rotation of the turbine rotor.

The speed compensator described in the paper has been designed to provide a unidirectional voltage varying with rotor speed which gives an almost level overall characteristic. The speed compensator does not depend on absolute rotor speed, and since it measures the rate at which the blades pass the pick-up, it is equally effective on any engine no matter how many blades there might be on the rotor.

Tests show that compensation is almost complete for blade tip frequencies up to 1000 blades per second, which was the maximum attainable with the mock-up laboratory turbine. It was found also that within this speed range the error in the peak voltmeter reading had been reduced to something less than 2 per cent, an error which is approaching those possible in the test meters themselves, and which represents only about 0·0007in in a 0·040in gap.

Instrument Controls

The controls comprise a rotary switch with "off" and four other positions, coarse and fine gain controls, and coarse and fine variable-resistance controls for bridge balance. The switch positions are as follow :—

(*a*) Off.

(*b*) Amplifier input short-circuited to earth. This switch position is used whenever the lead is disconnected from a pick-up or it is desirable to leave the instrument in a safe condition without actually switching off.

(*c*) Amplifier input bled to earth through a 1 kilohm resistor, so that overall sensitivity is low and the amplifier can handle large bridge out-of-balance voltages. This position is used during early stages of bridge balancing.

(*d*) Bridge coupled directly to amplifier giving maximum sensitivity ; the peak voltmeter is still in the leaky state. This position is used during final stages of bridge balancing.

(*e*) As in (*d*), but with the voltmeter reading peak voltage. This position is used for calibrating the instrument and making actual clearance measurements.

All the controls are mounted to the right of the indicating meter, so that they can be operated by a right-handed person without obscuring the view of the meter. A coaxial cable with a capacitance of 10 $\mu\mu F$ per foot is used for the external circuit. The total length of cable from pick-up to the main measuring equipment is 23ft, with the lead transformer inserted in the cable 10ft from the pick-up. The dimensions of the instrument are approximately 17·5in by 11in by 9·5 in, and the total weight including cable and lead transformer is 45 lb.

Using the Instrument

The operations involved in checking the blade clearances of a turbine engine can be classified under three headings : (*a*) balancing the bridge ; (*b*) calibrating the instrument ; (*c*) measuring a clearance.

Operation (*b*) needs to be done only once for an engine at any one time whilst (*a*) and (*c*) must be repeated at each pick-up point. All three operations are performed with the pick-up lead plugged into an actual pick-up on the engine, and they will now be described in detail under their separate headings.

Balancing the Bridge.—The bridge is balanced in two distinct steps. In the first step the bridge is balanced with the rotor stationary in whatever position it may have come to rest. Balance is reached by making successive adjustments of a variable capacitor in the lead-transformer box and the two bridge-resistance controls on the main instrument panel, until the reading of the peak valve voltmeter in its leaky state has been reduced to a minimum. In the second and final step of balancing, the rotor is spun and the variable capacitor is adjusted until the voltmeter reads zero. The bridge should now be balanced for minimum capacitance corresponding to the pick-up being opposite a gap between two adjacent blades.

Calibrating the Instrument.—Since the instrument is designed for use on all types of turbine engine, it becomes necessary to calibrate it in terms of the minimum safe clearance for the engine in hand. The scale of the variable capacitor in the bridge circuit is gauge marked to give a number of capacitance values which correspond to conditions of minimum safe clearance for various engines. Calibration involves selecting the appropriate capacitor setting and then adjusting the amplifier gain until the voltmeter reads 1·0 on the peak range. The capacitor is returned to the zero position and the instrument is then ready for use.

Measuring a Clearance.—To measure a clearance the rotor is spun, either using the starter motor or by hand cranking, and the reading of the voltmeter on the peak range, gives the smallest clearance, i.e. the clearance of the longest blade at this particular pick-up point. The measured clearance is read off as a fraction of the safe minimum clearance used in calibrating the instrument. For example, if for a particular engine the minimum safe clearance to which the instrument has been calibrated is 0·040in, an actual clearance of 0·060in would be indicated by a meter reading of 1·5, 0·030in by 0·75 and so on. By repeating the clearance measurement at each of the pick-up points around the shroud ring any distortion therein is readily apparent.

Test on a Mock-Up Engine

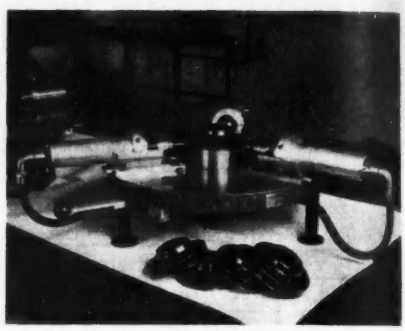
The laboratory mock-up engine consisted of the shroud ring and rotor from the turbine of a W2/700 turbo-jet engine, and could be driven at any speed up to 1100 r.p.m. by a d.c. motor. The feathered tips of the blades were ground flat, and all blades with the exception of three were shortened to the same length. The odd three were graded in 0·005in steps, the shortest of them being 0·004in longer than the equal-length blades remaining in the rotor. These three blades were push fits into the rotor slot and were thus used to give variable tip clearance. In addition, a spare blade was modified to take tips of different thicknesses, whilst the clearance was adjustable by inserting shims between the tip-fixing flanges. This blade, which was interchangeable with any of the other three test blades, was used to investigate the effect of blade thickness on the indicated clearances.

Test results show that although there is a slight increase in sensitivity with increasing blade thickness, measured in volts per 0·001in, any such changes in sensitivity are very small compared with the changes in blade thickness producing them. It follows that only small errors are incurred in assuming the sensitivity to be independent of blade thickness and using a fixed meter scale.

A test was performed to determine what effects, if any, conducting paths across the pick-up, such as carbon which may be deposited in normal service, might have on the reliability of the clearance measurements. Fixed resistors of 3 megohms and 1·45 megohms were connected in turn across the pick-up, to simulate leakage paths, the results showing the instrument to be practically unaffected by leakage across the pick-up for values down to 1·5 megohms, which was considered to be as low as is ever likely to be encountered in service.

Pneumatic Power Units

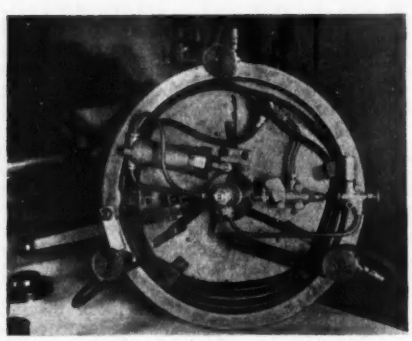
Particulars of some recent applications of its pneumatic equipment have been sent to us by Desoutter Brothers, Ltd., The Hyde, Hendon, London, N.W.9. In one of these applications three standard portable pneumatic tapping units are mounted on slides in a special radial tapping



Radial Tapping Machine

machine, designed for tapping three holes round the sides of plastic lampshade holders. The machine was designed and made by the Gildersleeve Design and Tool Company, Ltd., Reigate.

In this machine, shown in the illustrations on this page, the operator places the component on a pillar mounting in the centre of the cast

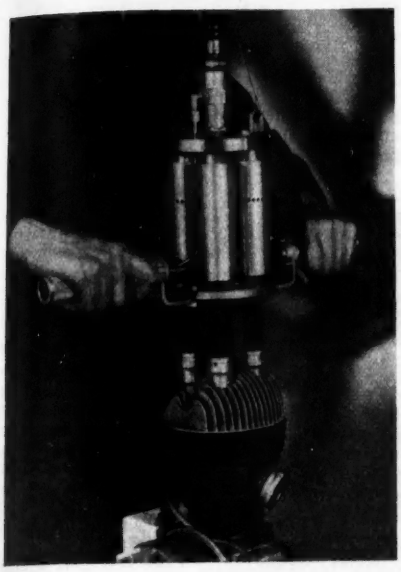


Mechanism of Radial Tapping Machine

aluminium base plate. With the component registered in the correct position, the operator opens a vertical air valve by pressure through a central hole in the top of the component. This valve admits air under pressure to a pneumatic cylinder below the base of the fixture. The plunger of this cylinder, to be seen in our second illustration, moves outwards for a roller on its

end to contact the arm of a central boss with a plate cam fixed to its lower face. The boss is turned against the tension of a return spring and through three links draws the tapping head slides in to the work. At the same time, the plate cam presses open an air control valve, through which a supply of compressed air is admitted to the three tapping heads.

The rotating spindles continue to advance and thread the holes in the component until the operation is completed, when the operator releases his pressure on the initial air supply valve. As the supply of air is cut off, the return spring comes into effect to turn the boss to its start position at the same time returning the



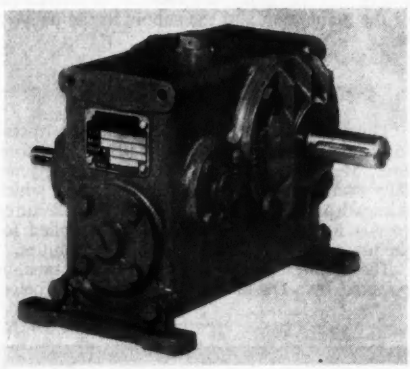
Multiple Torque Units

tapping slides and shutting off the supply of air to the tapping heads. Prior to tapping, the components are drilled on a similar fixture fitted with pneumatic drill heads.

For use when it is required to tighten groups of nuts, such as on a cylinder head, the firm is now making multiple torque units as shown in another illustration. These units are fitted with a group of "S.R.50" pneumatic motors, each of which is designed to develop nearly ¾ h.p., with a torque of 500 pounds-inches. By adjusting the pressure-regulating valve at the feed line coupling, the precise degree of torque can be uniformly applied to all nuts in a group. We are informed that units of this type can be built with any number of motors to any required pattern specified. The unit illustrated weighs about 25 lb.

A Small Double Reduction Worm Unit

A COMPACT form of double reduction "Radicon" worm reduction unit has been introduced by David Brown Gears (London), Ltd., Stonebridge Park Works, London, N.W.10, for drives where speeds are very low and the powers transmitted are small. These units are available for a wide range of output speeds with standard ratios varying from 65 to 1 to 3600 to 1, and special units can be supplied up to a maximum reduction of 10,000 to 1. With each pair of worm gears in a unit, reductions varying from 5 to 1 to 60 to 1 are obtained, and input speeds range from 500 r.p.m. to 3000 r.p.m. In the



A Small Double Reduction Worm Gear

standard units, one of which we illustrate herewith, all the gears are right hand, giving the same direction of rotation of both input and output shafts.

The worms and wormwheels used in the new units are similar to those used in the firm's 1½ and 1⅝ single reduction units. The worms are integral with their case hardened steel shafts and the wormwheels of "Taurus" bronze are keyed to the intermediate and low speed shafts. All shafts are fitted with dual purpose bearings, and oil seals are provided on the input and output shafts. Detachable feet fitted to the rigid cast iron case can be mounted in alternative positions to adapt the units for easy installation. If required, units can be fitted directly to a motor by means of adaptors which are integral with the worm shaft end covers. The makers point out that these adaptors cover all makes of fractional horsepower motors.

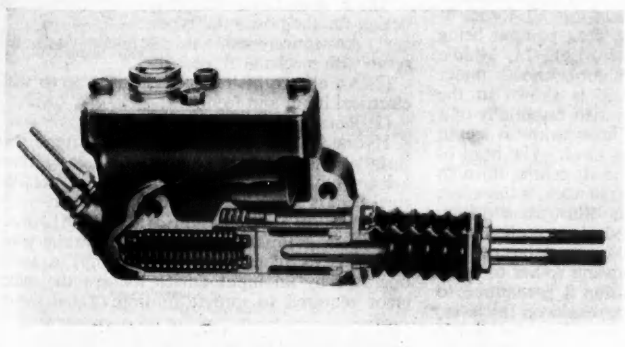
A Hydraulic Clutch Control

THE tendency in modern car design towards a reduction in weight with an increase in brake horsepower has also brought into prominence new problems of vibration, drumming and rattle. Much has been done to overcome these defects, but with present-day flexible engine mountings, a prolific cause of trouble is the mechanical linkage between the clutch pedal and the clutch withdrawal mechanism. The vibration transmitted in this way becomes an unpleasant "judder" at the pedal, and is often blamed, quite unfairly, on the operation of the clutch itself.

One method of eliminating any transfer of movement from the engine and clutch to the pedal is by means of hydraulic linkage through a flexible pipe. Our illustration shows a unit which has recently been introduced by the Lockheed Hydraulic Brake Company, Ltd., of Leamington Spa. The clutch pedal operates a hydraulic master cylinder, which, for the sake of simplicity and low cost, is incorporated with the hydraulic brake master cylinder, to form a twin bore unit with separate tanks and common filler for the fluid. Pressure on the pedal forces fluid, via a flexible pipe, into a small slave cylinder which operates the clutch release mechanism. The almost complete absence of friction in the system gives a positive operation and suitable leverage arrangements provide a lighter clutch pedal.

Maintenance is also reduced to a minimum as the enclosed hydraulic system, which is self-lubricated, does away with the necessity for lubrication points in a very inaccessible part of the chassis.

The simplicity of this system is noteworthy and the mechanism takes up little more space than the normal hydraulic brake equipment.



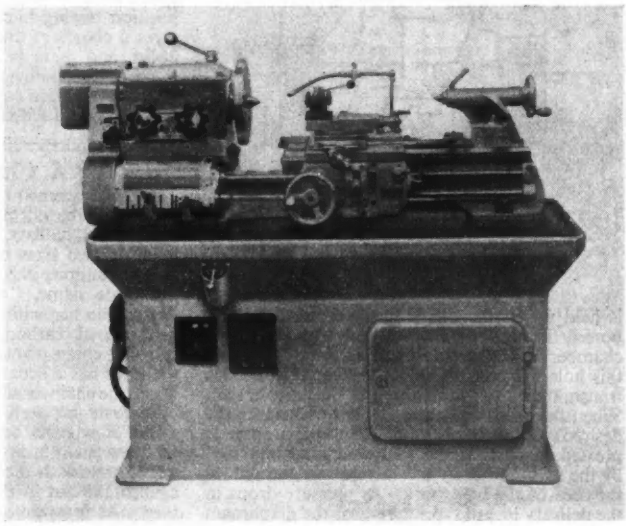
Hydraulic Clutch Control Master Cylinder

A 5½in Precision Lathe

A NEW 5½in lathe for precision toolroom or production work, which is now being made by Kerry's (Great Britain), Ltd., Warton Road, London, E.15, is illustrated below. This machine has a rigid cast bed adequately ribbed to avoid deflection, and mounted on a substantial cast iron cabinet. It is made with two bed lengths, of 48in or 65in, and swings work up to 11in diameter over the bed or 17in in its 4in wide gap.

The all-geared headstock of the machine is driven from a 1 h.p. 1420 r.p.m. motor through belts and a headstock pulley running at 650 r.p.m. A dry-plate clutch transmits the drive from the headstock pulley and the clutch lever also operates a brake. The spindle is bored 1in diameter and is carried on adjustable Timken taper roller bearings at the nose and an adjustable phosphor bronze bearing at the rear. The eight spindle speeds available through the machine-cut gearing in the headstock range from 39 r.p.m. to 1500 r.p.m. An adaptor is supplied to enable the machine to be used for collet work up to ⅝in diameter if required. Spindle speeds are selected by setting of the two indicator discs to be seen at the side of the headstock in the photograph.

An improved cross slide and compound rest is fitted to the machine and the rest, which is graduated to 180 deg., can be swivelled to any angle on each side of the central position. A single control handle actuates hand or power traverse for cross or longitudinal feeds. Through the feed box sixty-two English pitches and sixty metric pitches can be selected. There are seven sliding and surfacing feeds ranging from 0·000375in to 0·024in per spindle revolution in geometrical progression when using the inch change gearing, the drive being transmitted



A 5½in Precision Lathe

through a separate feed shaft. When the metric change gears are used twenty-eight feeds are obtainable.

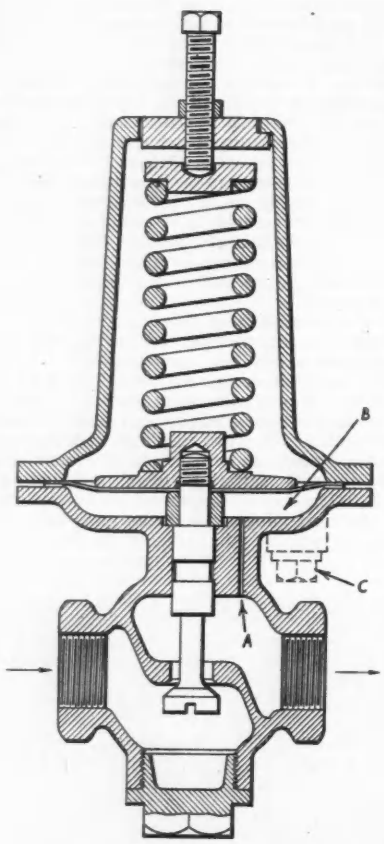
The tailstock is carried on separate vee and flat ways from the saddle, and is fitted with a graduated barrel. For taper turning purposes, the tailstock has means of side adjustment.

Reducing Valves

A RECENT addition to the range of reducing valves made by Sir W. H. Bailey and Co., Ltd., Patricroft, Manchester, is a new "Class A Foster" valve for steam, air, water or gases. These valves are particularly suitable for medium and low-pressure applications, and are available in six sizes from ¼in to 2in. In them an initial pressure of up to 250 lb per square inch can be lowered in one reduction to 5 lb per square inch, and the range of outlet pressures extends from 5 lb to 125 lb per square inch.

As can be seen from the drawing we reproduce, the valves are of a straightforward design, with no glands or packing, and all parts are readily accessible for maintenance and inspection purposes. The valve stem is fixed to a phosphor-bronze diaphragm held between the main body and a cast aluminium spring chamber. A spring, the loading of which can be adjusted by means of a bolt projecting from the top of the case, presses on the diaphragm to hold the valve open.

In operation, the gas or liquid at high pressure passes through the valve port in the body to the delivery chamber whilst the valve



Reducing Valves

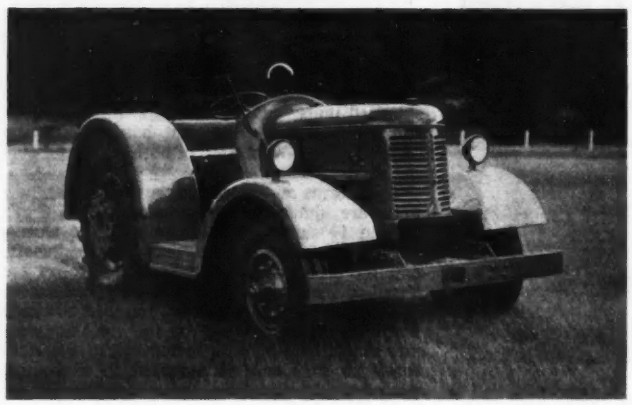
is held up by the diaphragm. A small hole *A* bored through the valve body leads to the chamber *B* above the diaphragm, and through this hole the pressure in the delivery chamber is transmitted to the top of the diaphragm. When the pressure on the diaphragm reaches the desired delivery pressure, the diaphragm is pressed down against the pre-set load imparted by the spring to draw the valve down and reduce the area of the inlet port. As pressure drops in the delivery line the spring returns the diaphragm to lift the valve and admit more gas or liquid and restore the pressure. The range of springs supplied covers pressures from 5 lb to 60 lb per square inch, 20 lb to 80 lb per square inch, and 40 lb to 125 lb per square inch.

If the demands in the delivery line fluctuate rapidly a separate remote control means to speed up the operation of the valve can be fitted. In such a case a separate tube of small bore is fitted between the point in the delivery line, where sudden heavy demands are made, and the gland *C* on the diaphragm chamber. The pressure changes in this pipe then control the movement of the diaphragm and the supply to the delivery line.

An Industrial Tractor

THE accompanying illustration shows a tractor for haulage work which David Brown Tractors, Ltd., Meltham, Yorkshire, is now making generally available. Up till now, this tractor, which is known as the "VIG/1C," has been manufactured to Air Ministry specifications and supplied for the towing of aircraft and other airfield duties.

The tractor, which weighs nearly 5 tons, is powered by a David Brown four-cylinder petrol



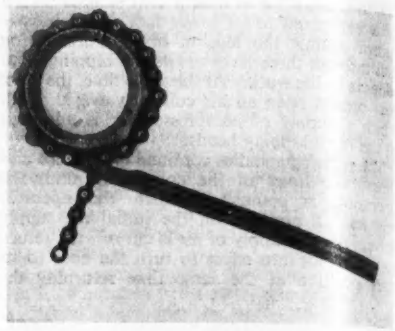
An Industrial Tractor

engine, 3½in bore by 4in stroke, developing 41 b.h.p. at a maximum speed of 2300 r.p.m., and giving a drawbar pull of rather more than 7000 lb. Transmission is through a Borg and Beck single dry-plate clutch, operating in conjunction with a self-priming Brockhouse turbo-transmission unit, with a torque multiplication ratio of 3 : 1. The final drive is taken through spiral bevels at the differential to spur reduction units at the wheels. The rear wheels are fitted with 16in Girling internal-expanding brakes, and Clayton-Dewandre vacuum servo trailer braking is also provided. The gearbox provides for three forward speeds, from 1·45 m.p.h. in first gear to 12·22 m.p.h. in top, and a reverse speed from 1·94 m.p.h. to 4·47 m.p.h. A six-position towing hitch at the rear of the tractor gives a choice of drawbar height, from 13¾in to 26¼in, and there is a front towing hitch which is centrally mounted on the bumper bar. The tractor's standard equipment includes a 15,000 lb line pull winch with sprag.

A Chain Wrench

A CHAIN wrench of particularly simple design, which can be effectively used on all forms of nuts, pipes, collars, shafts, &c., is now being made in two sizes by Melvin, Ltd., 2A, Middle Lane, London, N.8. This tool, known under the trade name, "Gripital," is shown in the illustration herewith. It consists essentially of a heat-treated carbon steel lever with a length of roller chain pivoted at its head. The head of the lever has a square hole in its centre, through which the chain, used to grip the work, is threaded.

As can be seen in the illustration which shows a wrench being used to unscrew a large nut, the chain is first passed round the nut and pulled taut with the lever swung round to press against the nut in the direction it is required to turn. As pressure is then increased on the lever, the chain automatically locks in the slot and is drawn into firm contact with the whole periphery of the nut, before the full unscrewing pressure



A 7-in Lever Chain Wrench

is applied. If it is required to oscillate the lever through a small arc, as would be required when unscrewing a nut in a confined space, a "ratchet" motion can be obtained by maintaining the free end of the chain taut with a light finger pressure against the lever during the return motion.

The large number of point contacts made by the chain links on a nut or collar during turning and the even distribution of the load imparted by the lever, reduces to a minimum the tendency to dig in and mark the work. Where considerable force has to be exerted on machined faces, an intermediate packing of emery cloth between the chain and work further reduces marking.

The 7-in lever wrench we illustrate is the smallest size made and it is designed for operation on hexagons from 1in to 2¾in across the flats, or round objects, such as collars or shafts, from 2in to 3½in diameter. A heavy-duty wrench, with a 14in lever, and fitted with a chain having a breaking strain of 5000 lb, is made for work of from 2in to 4¼in diameter.

We had an opportunity to test these wrenches and after a few minutes use found them easy to apply and use, and capable of exerting an even and powerful grip without any signs of slipping when used for turning a variety of nuts, pipes, collars, &c.

An Introduction to Hydraulic Servo-Mechanism Theory*

By H. G. CONWAY, M.A., M.I.Mech.E.,† and E. G. COLLINSON, B.Sc.‡

No. I

Types of Hydraulic Servo Systems

As with other servos, there are two main types of hydraulic servo, namely, positional controls and velocity controls, or governors (types of higher order are occasionally encountered but are outside the scope of this paper).

There are three categories of mechanical design for the positional types :—

(1) An entirely mechanical linear positional servo with mechanical feedback.

(2) An electro-hydraulic positional servo with electrical input and feedback.

(3) Rotary hydraulic transmission.

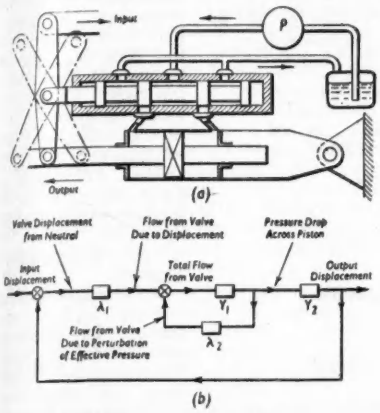
Hydraulic governors are used on important installations and, while many of their features are common to the types discussed here, detailed treatment is outside the scope of the paper.

Mechanical Servo.—Fig. 1(*a*) shows the hydraulic line diagram of an ordinary hydraulic positional servo, consisting of a pump, a valve operated by an input device to give the usual error required to initiate motion of the servo,

* From a Conference on Hydraulic Servo-Mechanisms. Institution of Mechanical Engineers, February 13th. Extracts.

† Technical director, British Messier, Ltd., Gloucester.
‡ Chief technician British Messier ,Ltd. Gloucester.

a hydraulic jack or cylinder and a feedback link used to cancel the error on the valve. The operation of this type of servo is well known. When the input end of the "differential lever" is moved, the output end being momentarily fixed, the valve is opened. Flow of oil then takes place, moving the actuating jack and output, and at the same time moving the differential lever to cancel the "error" originally introduced. It will be noted that the maximum valve opening limits the maximum error which can be applied to the system. There is an important



a Line diagram *b* Block diagram

Y_1—Transfer function connecting pressure drop p_c and flow q
Y_2—Transfer function connecting output displacement and pressure drop p_c.
λ_1—Slope of flow pressure drop curve, Fig. 6*b*.
λ_2—Slope of flow valve opening curve, Fig. 6*a*.

Fig. 1—Mechanical Servo

particular case of this mechanism, when the lever length is zero; in other words, the valve is mounted on the moving part of the jack so that the body of the valve follows up the motion of the valve spool. Fig. 1(*b*) shows the corresponding block diagram of the type commonly used by the servo theoretician.

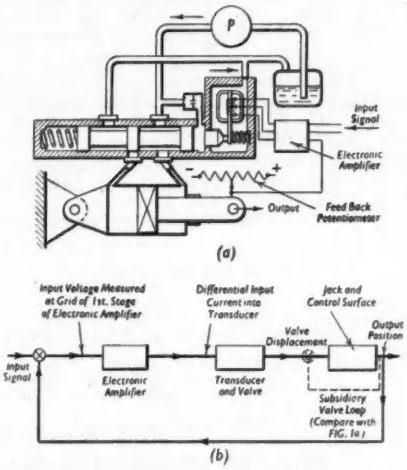
Electro-Hydraulic Servo.—Fig. 2(*a*) shows an electro-hydraulic servo consisting of a pump, a valve operated by an electrical device—generally called a transducer—to create the error to operate the valve, a hydraulic jack or cylinder, and an electric feedback link into the amplifier which gives the initial signal to the transducer. The transducer and the feedback device may, for example, form two arms of an electrical bridge system. The operation of the particular system illustrated is as follows: the valve is a three-way type, the jack being continually pressurised on the annular end. The valve spool is spring-urged one way and pressure-balanced by a controlled bleed flow. This bleed allows the pressure in the chamber at the end of the valve spool to be varied proportionately to the current in the transducer which controls the opening of the bleed flow orifice, Fig. 2(*b*) shows the corresponding block diagram.

Rotary Hydraulic Servo.—Fig. 3(*a*) shows the

Notation.

A—Area of jack piston.
B—Viscous damping.
C—Clearance.
D—Diameter of valve.
d—Diameter of valve inlet connection.
E—Valve opening.
e—Perturbed valve opening $=\theta_i-\theta_o$.
F—Load, force.
H—Power delivered by valve.
I—Current.
K—A parameter = rate of flow per unit valve opening.
L—Length of valve lands.
M—Mass.
P_c—Pressure drop across load.
P_s—Pressure drop across supply.
p_c—Perturbed pressure drop.
Q—Flow.
q—Perturbed flow.
s—Laplace operator.
T_1, T_2—Time constants.
t—Time, seconds.
V—Voltage.
v_c—Perturbed piston velocity.
x—Input voltage.
Y_1—Transfer function connecting pressure drop p_c and q.
Y_2—Transfer function between output displacement and pressure drop p_c.
y—Input current
z—Displacement of valve spool.
θ_i—Perturbed part of input signal.
θ_o—Perturbed part of output displacement.
λ_1—A parameter $=\partial Q/\partial E$.
λ_2—A parameter $=\partial Q/\partial P_c$.
μ—Loop gain constant.

rotary transmission hydraulic servo, which is somewhat similar to the first type, but has certain features of its own. It consists of a variable-stroke hydraulic pump which can deliver oil in either direction to a rotary hydraulic motor or, in some cases, a hydraulic jack. The input signal is used to vary the output and



a Line diagram *b* Block diagram

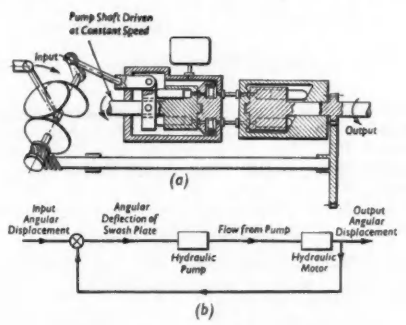
Fig. 2—Electro-Mechanical Servo

direction of flow of the hydraulic pump operating directly the hydraulic motor or jack. A mechanical, or even electrical, feedback link can be used. Fig. 3(*b*) shows the corresponding block diagram.

The simple mechanical servo is by far the most widely used and has everything to commend it, except that the input force required to operate the valve is relatively high compared with the operating force available in many practical applications of sensitive servos.

The electro-hydraulic servo is generally used where the input signal is derived from some electronic device and is of low power, The third system is of particular utility when a rotary motor is required to move the output, for example through a number of turns, but a variable-stroke pump and linear jack system has generally less to commend it than the more simple system shown in Fig. 1. The input operating load (controlling effort) on a variable-stroke pump will, in general, be greater than on a valve-operated mechanism.

Hydraulic velocity-governors generally make use of a Watt flyball governor rotated by the device being governed, and arranged to adjust the position of a valve spool to regulate the oil flow to a jack or actuator. The jack or actuator then moves some element of the machine to change its speed, which is fed back to the



a Line diagram *b* Block diagram

Fig. 3—Rotary Transmission Hydraulic Servo

governor as a change of velocity. Generally, such servos are used on machines with large inertia, resulting from their rotation; the tendency to hunt may be appreciable and many practical systems are consequently highly sophisticated§. However, since the governor is rotating, it can often be arranged, without much complication, to rotate an anti-friction sleeve in the valve to eliminate "stiction" forces (see later).

§ The use of the word "sophisticated" in this sense is more idiomatic in this field than grammatical.

Theoretical Performance Requirements

Theoretically, the perfect servo would respond to a step function input by a correspondingly similar output. If a sinusoidal input were applied to it, it would respond with a corresponding sinusoidal output with no attenuation and no phase lag. In practice, none of this occurs. Consider, for instance, the particular servo system shown in Fig. 2(*a*). This can be analysed, to a first approximation, as follows.

The force on the slide valve spool due to hydraulic pressure is balanced by a spring and an internal damping force (viscous friction), the inertia effects of the spool being neglected at low frequencies. Also, it is known that the hydraulic pressure is proportional to the input current y so that :—

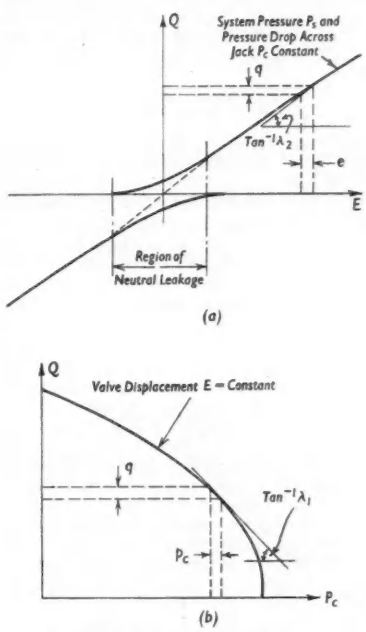
$$\mu_1 y = z + T_1 \dot{z},$$

where z is the displacement of the valve spool at any time, and μ_1 and T_1 are constants. Thus the transfer function relating the valve displacement z to the transducer input current y is :

$$z = \frac{\mu_1 y}{1+sT_1}$$

s being the Laplace operator. Thus the overall dynamic response of the valve itself is equivalent to a simple time constant delay, this having been confirmed on test.

In regard to the remainder of the control,



a With valve displacement from neutral.
b With pressure drop across the jack piston.

Fig. 4—Variation of Valve Flow

since it is essentially non-linear, small perturbations only are considered.

The flow through the valve to the jack is given by :

$$Q = KE\sqrt{\frac{P_s - P_c}{2}}$$

where E is the valve opening, P_s is the supply pressure, and P_c is the pressure-drop across the load.

The perturbed flow is then given by

$$q = \lambda_1 z - \lambda_2 p_c,$$

where, as before, z is the perturbed valve displacement, and p_c is the perturbed part of P_c.

The parameters λ_1, λ_2, are defined by :

$$\lambda_1 = \frac{\partial Q}{\partial E} \qquad \lambda_2 = \frac{\partial Q}{\partial P_c}$$

both being evaluated at the operating point considered. They are, in fact, the slopes of the

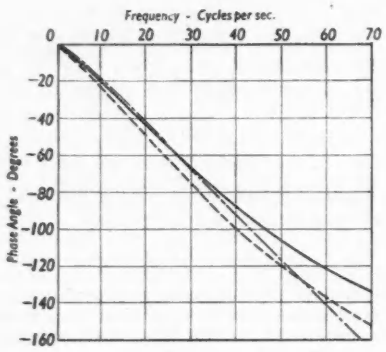
flow-valve opening (Fig. 4(*a*)) and flow-pressure drop curves (Fig. 4(*b*)) for the valve.

Neglecting the compressibility of the fluid, then $q=2Av_c$, where $2A$ is the larger area of the jack piston, and v_c is the perturbed piston velocity.

Finally, the jack operates against a load F, a mass M, and viscous damping B in the transmission pipes. Thus considering only the perturbed parts of these forces :

$$Ap_c=M\ddot{\theta}_o+B\dot{\theta}_o,$$

where F is assumed constant. Variations of this would be considered only as a disturbance.



——— Calculated $\frac{\theta_o}{\theta_i}=\frac{200}{s(1+0\cdot003s)+200}$.

– – – – Calculated $\frac{\theta_o}{\theta_i}=\frac{200}{s(1+0\cdot003s)(1+0\cdot001s)+200}$.

——— Measured phase angle.

Fig. 5—Phase Lag Diagram

The term θ_o is the perturbed part of the output displacement.

Combining the above equations for z, q and p_c gives

$$z=\frac{s}{\lambda_2}\left[\left(2A+\lambda_2\frac{B}{A}\right)+\frac{\lambda_2 Ms}{A}\right]\theta_o$$

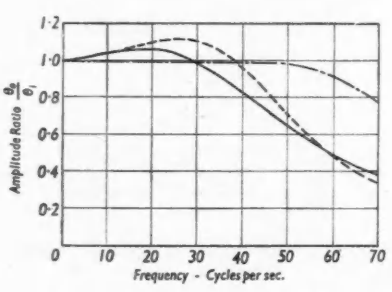
This can be written in the form:

$$\theta_o=\frac{\mu_2 z}{s(1+sT_2)}$$

where

$$\mu_2=\frac{A\lambda_1}{2A^2+\lambda_2 B} \text{ and } T_2=\frac{\lambda_2 M}{2A^2+\lambda_2 B}$$

Since the input current into the transducer



——— Calculated $\frac{\theta_o}{\theta_i}=\frac{200}{s(1+0\cdot003s)+200}$.

– – – – Calculated $\frac{\theta_o}{\theta_i}=\frac{200}{s(1+0\cdot003s)(1+0\cdot001s)+200}$.

——— Measured.

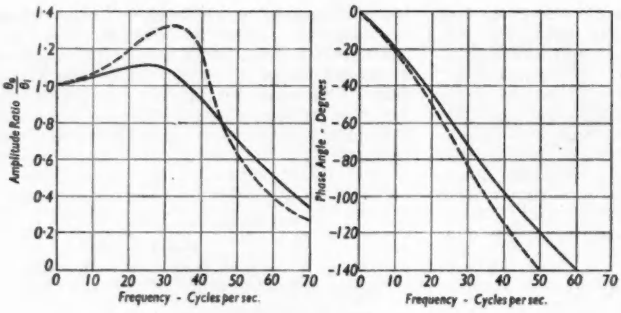
Fig. 6—Amplitude-Ratio Diagram

is proportional to the error $y-\mu_3(\theta_i-\theta_o)$ and hence for the overall loop

$$\frac{\theta_o}{\theta_i-\theta_o}=\frac{\mu_1\mu_2\mu_3}{s(1+sT_1)(1+sT_2)}=\frac{\mu}{s(1+sT_1)(1+sT_2)} \quad . \quad (1)$$

This is the general loop transfer function, being of the third order and containing the two time constants T_1 and T_2.

If, however, the operating point considered


Amplitude Ratio $\frac{\theta_o}{\theta_i}$
1·4 1·2 1·0 0·8 0·6 0·4 0·2 0
0 10 20 30 40 50 60 70
Frequency - Cycles per sec.
Phase Angle - Degrees
0 -20 -40 -60 -80 -100 -120 -140
0 10 20 30 40 50 60 70
Frequency - Cycles per sec.

a With amplitude ratio.

——— Time constants 0·003 and 0·001 second, calculated

amplitude ratio $\frac{\theta_o}{\theta_i}=\frac{200}{s(1+0\cdot003s)(1+0\cdot001s)+200}$.

– – – – Time constants 0·003 and 0·002 second, calculated

amplitude ratio $\frac{\theta_o}{\theta_i}=\frac{200}{s(1+0\cdot003s)(1+0\cdot002s)+200}$.

b With phase angle

——— Time constants 0·003 and 0·001 second, calculated

phase lag $\frac{\theta_o}{\theta_i}=\frac{200}{s(1+0\cdot003s)(1+0\cdot001s)+200}$.

– – – – Time donstants 0·003 and 0·002 second, calculated

phase lag $\frac{\theta_o}{\theta_i}=\frac{200}{s(1+0\cdot003s)(1+0\cdot002s)+200}$.

Fig. 7—Effect of Variation of Secondary Time Constant

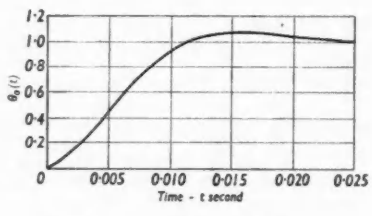
is the valve at neutral ($E=0$), then $\lambda_3=0$ and $T_2=0$. In this case the loop transfer function is

$$\frac{\theta_o}{\theta_i-\theta_o}=\frac{\mu}{s(1+sT_1)} \quad . \quad . \quad . \quad . \quad (2)$$

It is thought from the nature of experimental test results that this equation holds quite well at low frequencies whilst at increasing frequencies the valve opening is such that non-linearities provide an effective time constant T_2.

The curves shown in Fig. 5, giving the phase lag measured experimentally, show the quite good agreement with theory if the time constant is taken as 0·003 second and the gain μ is set at 200. In fact, the curves coincide up to a frequency of 40 c/s. The correspondence of the amplitude-ratio curves shown in Fig. 6 is not so good, however. The theoretical response to a step function input is shown in Fig. 8.

Any servo having a transfer function of the



To unit step function $\frac{\theta_o}{\theta_i}=\frac{200}{s(1+0\cdot003s)+200}$.

Fig. 8—Transient Response

form given in equation (2) is essentially stable, since in no circumstances can the phase lag exceed 180 deg. In a general case, however, instability can occur. The overall transfer function is

$$\frac{\theta_o}{\theta_i}=\frac{\mu}{s^3T_1T_2+s^2(T_1+T_2)+s+\mu}$$

and Routh's criterion says that the condition for stability is $(T_1+T_2)>\mu T_1T_2$, that is, the loop gain should be less than $(T_1+T_2)/(T_1T_2)$. This is a condition only of stability ; it does not give the maximum value of μ for a good control.

The time constant T_1 is dependent only on the physical dimensions of the valve. As seen from equation (1) it depends entirely on the viscous friction drag on the valve. It can be shown quite easily that this drag is proportional to LD/C where L is the length of the valve "lands," D is the valve diameter, and C is the radial clearance between the valve and its sleeve. If, however, the time constant is reduced by increasing the clearance C it must be remembered that the leakage rate will be in- creased as C^3.

The other time constant T_2 is much more complex, but at high operating pressure it is roughly proportional to M/B, that is, increasing the output damping reduces the time constant. However, this can be taken only so far, as otherwise the steady state performance will suffer.

It is thought that one of the main causes of inconsistent operation of this type of control may be the variation of the time constant T_2 throughout the operating cycle. From test, a mean value of T_2 on a certain valve is 0·001 second, and the curves in Fig. 7 are drawn for a gain of $\mu=200$. If this time constant is doubled then the effect on stability is immediately apparent.

It should be pointed out that the servo considered is essentially electro-hydraulic and "sophistication" is perhaps best done electrically. However, the improvement that can be made by the hydraulic engineer is in the improvement of the valve design and, in particular, his understanding of the effect of the valve and the other elements of the servo-loop on its overall performance.

Much of the trouble with a practical servo arises from the valve, the fact that it has to be prevented from leaking, generally with finite overlaps, and that it requires a not inappreciable force to operate it.

(*To be continued*)

Technical Reports

Statistical Survey of Overvoltages Observed During Switching Tests on a 66kV System with Arc-Suppression Coil and with Resistor Earthing. The British Electrical and Allied Industries Research Association (Ref. S/T60). Price 3s., postage 3d.—In 1942-44, an investigation was made by the E.R.A. on the 66kV system of the Shropshire, Worcestershire and Staffordshire Electric Power Company, for the purpose of finding the cause of troubles which had occurred on some of the lines following the installation of Petersen coils in 1940. For this investigation about 170 switching tests were made and records were taken by electromagnetic oscillograph, c.r.o. and klydonograph. E.R.A. report Ref. S/T50 deals with the results of these tests. The cause of the trouble was traced to a small number of insulators of an obsolete type which were liable to flashovers on the occurrence of switching surges. After they had been replaced by a modern type no more trouble occurred.

Having regard to the large number of tests which had been made it has been considered desirable that a statistical survey should be made of the overvoltages recorded. This forms the subject of the present report.

National Building Studies Special Report No. 19, "The Assessment of Vibration Intensity and its Application to the Study of Building Vibrations." D.S.I.R. H.M. Stationery Office. Price 1s.—This report from the Building Research Station reviews existing scales of vibration intensity, including earthquake scales, and concludes that one scale obtained from experiments with human beings is applicable to normal industrial vibrations. Generally, structural vibrations would have to go over the "painful" level on this scale, it is stated, before there is any possibility of damage to the structure, and almost certainly, anyone in a building would have to leave it because vibrations as great as this would be unbearable. There is, therefore, a tendency to overestimate the movement taking place in a building, and damage is extremely unlikely to occur.

Examination of Corroded Insulator Spindles. By G. Mole, Ph.D., F.Inst.P. The British Electrical and Allied Industries Research Association (Ref. O/T8). Price 9s., postage 3d.—Examination of insulator spindles which had been in service for periods varying from seven months to forty-three years, mainly in three areas, has revealed that a corrosion process occurs where galvanised spindles are fitted into lead thimbles, which may materially shorten the life of the spindles. Methods of protection are suggested.

Industrial and Labour Notes

British Overseas Trade

Provisional figures issued by the Board of Trade put the value of United Kingdom goods exported during January at £217,900,000, compared with a monthly average last year of £212,500,000. There were twenty-seven working days in January — one more than in most months of the year. The export total includes £25,000,000 which represents the value of goods shipped to Canada and the U.S.A. in January. That figure is much the same as the monthly average in the fourth quarter of last year. The value of January imports is stated to have been £290,100,000, or exactly the same as the monthly average last year. Re-exports in January have been valued at £10,100,000 so that the trade deficit for the month amounted to £62,100,000. Last year, the deficit averaged £65,700,000 a month.

The Board of Trade has also made a statement, within the past week, about the pattern of the United Kingdom's trade in 1952. One of the points emphasised in it is the reduction of £462 million, compared with 1951, in imports from non-sterling sources, against which has to be set an increase of £40,000,000 in the value of imports from the sterling area due to larger supplies of oil from the Middle East. Dollar imports, which were already subject to control, decreased by £53,000,000. Imports from O.E.E.C. countries decreased by £151 million, but were still substantially more than in 1950, whereas imports from other non-sterling countries decreased by £258 million to £466 million, which was £16,000,000 below the 1950 figure. Another matter mentioned in the statement is the decrease of £115 million last year in this country's total export trade with the independent members of the sterling area, following a big expansion in 1951. As by the second half of last year the value of our exports to those countries was 7 per cent below the 1950 average, the decrease in volume must have been more. The Board of Trade goes on to say, however, that the effect of this decline on our trade with the sterling area was mitigated by an increase in exports to the Colonies and other dependent territories between 1951 and 1952 of £52,000,000. Exports and re-exports to the dollar area increased last year by £25,000,000 and to non-sterling O.E.E.C. countries by £22,000,000, but exports to the remaining non-sterling countries in total fell away sharply towards the end of the year, and for 1952 as a whole, were up by only £3,000,000 compared with 1951.

A question about the volume of exports in the third and fourth quarters of last year was addressed to the President of the Board of Trade in Parliament last week. In his reply, the President said that the volume of United Kingdom exports in the third quarter was 14 per cent less, and in the fourth quarter 7 per cent less than in the corresponding quarters of 1951.

Coal Miners' Wages

Another meeting between the National Coal Board and the executive of the National Union of Mineworkers was held in London on Thursday of last week, as a result of which underground and surface day wage workers are to receive an increase of 6s. a week. This means that the national minimum rate for underground workers will be £7 6s. 6d. a week, and for surface workers, £6 7s. 6d. It has been stated that the increase, which becomes effective this week, will add about 6d. a ton to the cost of coal getting.

A joint statement, which was issued after the meeting, said that the union executive would co-operate with the Coal Board in a campaign to inform managements and men of the facts existing in the industry and to emphasise that the well-being of the coal industry and the country depends upon a true spirit of co-operation and a determination to improve efficiency. Joint committees of representatives of the Coal Board and the National Union of Mineworkers are to be set up in every division to consider and initiate measures to improve efficiency and remove difficulties at pit level.

The executive committee of the union has agreed to recommend that the extension of hours agreement shall be continued for a further twelve months from the end of April, and will do its best in all areas to ensure that the Saturday shift is worked at all pits. Finally, at the meeting last week the representatives of both sides of the industry agreed that work on the revision of the wages structure should be continued.

Researches into the Human Factor

A lecture-discussion course for directors and senior management on "Recent Researches into the Human Factor" began at the Birmingham College of Technology on Thursday of last week. The course consists of five lectures.

The first of these lectures was given by Sir Charles Renold and was entitled "The Aim of Joint Consultation." Sir Charles said that, speaking very broadly, the term "joint consultation" connoted in his mind forms of discussion that were concerned with working out acceptable ways and means against a background of common interests, as contrasted with the negotiation of a compromise on a balance of strength of opposing interests. He urged that it was an indispensable condition of happy relations in industry that the people engaged should feel that they counted as individuals. That, Sir Charles said, had the greatest significance in the domestic relations within the individual establishment.

Within the establishment, Sir Charles continued, there were two lines of approach to making people feel that they count; they were good leadership acting through the normal chain of command, and devices of joint consultation cutting across the line. The first, Sir Charles suggested, was fundamental, and the second, whilst having an essential contribution to make, was supplementary and must be so devised and handled as not to weaken the first. Joint consultation, Sir Charles emphasised, must be about things that matter. It should stress the community of interests within the establishment, but it should not attempt to substitute establishment loyalty for trade union loyalty. There should be scope for both.

Industrial Activity in Scotland

At the annual meeting of the Clydesdale and North of Scotland Bank, Ltd., which was held last week, Sir Andrew Macharg, deputy chairman, read the statement prepared by the chairman, Sir Harold Yarrow, who is at present abroad. In the course of the statement, reference was made to the widely held opinion that the continued excessive burden of taxation was crippling industrial development. It became increasingly apparent that, after payment of income tax, profits tax and, in some cases, excess profits levy, industry was largely deprived of the resources which would normally be applied in modernisation and expansion.

Sir Harold Yarrow's statement went on to say that industrial activity throughout Scotland was again maintained at a high level last year, although the record was uneven. All sections of industry experienced an intensification of foreign competition, while some suffered severely as a result of more stringent import licensing policies adopted by several overseas countries. Heavy engineering firms continued to be actively engaged, though a tapering off in the volume of new orders, particularly from overseas, was noticeable towards the end of the year. Shipbuilders also held substantial orders, mainly owing to the demand for oil tankers, which represented about one-half the total tonnage; but here, again, the statement commented, there was growing evidence of valuable contracts being diverted to foreign competitors, who could offer lower prices and speedier deliveries for some classes of vessels. Scarcity of steel had been the shipbuilders' main problem and had kept activity in all yards well below capacity. Somewhat better prospects existed for the current year, and, Sir Harold's statement said, if official steel allocations were increased and met, with deliveries in proper sequence, both engineers and shipbuilders would be in a more favourable position to tackle the problem of foreign competition by the more efficient employment of their productive resources.

Sir Harold's statement then went on to some observations on the export trade, saying that we must now be in a position to quote attractive prices and to offer suitable delivery dates to buyers who had a wide field of choice. In other words, competition was once more the prevailing condition, and it was likely to become increasingly keen in the future, especially from manufacturers less handicapped by taxation than those in this country. For Britain the position was one of serious challenge. We should not be misled, Sir Harold's statement declared, by the relatively easy markets since the war and by the resultant high level of employment at home. All responsible sections of the community agreed that full employment was desirable. But its maintenance depended upon the country's success in the export field, which, in turn, depended upon the ability to quote fixed competitive prices.

Iron and Steel Prices

The Minister of Supply, Mr. Duncan Sandys, has made two Orders effecting some minor changes in iron and steel prices. Both Orders came into operation on February 11th. The first, entitled the Iron and Steel Scrap (Amendment No. 1) Order, 1953, increases the controlled maximum delivered prices of iron and steel scrap to allow for the recent rise in transport charges. The increases in scrap prices range from 11d. to 1s. 11d. a ton.

The second Order, entitled the Iron and Steel Prices Order, 1953, increases the maximum prices of a small number of iron and steel products which were unduly depressed in relation to the general price level. The Order also authorises some increase in the extra charges which may be made for the delivery of certain descriptions of steel to places distant from the steel works. The products principally affected are acid steel billets, tube steel, railway axles, and certain classes of pig iron, the prices of which products are being increased by between 0·75 per cent and 8 per cent. Apart from these products, the general level of iron and steel prices is not appreciably affected.

The Steel Scrap Drive

In the latest issue of its *Monthly Statistical Bulletin*, the British Iron and Steel Federation surveys the progress of the scrap campaign during 1952. It says that, although last year's increase in steel production was based mainly on improved supplies of pig iron, every effort was also made to procure the maximum tonnage of steel-making scrap. Of the 9,300,000 tons of scrap available to the steel works last year, 4,400,000 tons consisted of "own arisings," 4,200,000 tons were purchased within the United Kingdom, and the remainder was imported. It is estimated that the total supply of home-bought scrap to the entire iron and steel industry rose last year by about 470,000 tons, compared with 1951. The survey shows that, at the end of last year, stocks of scrap amounted to more than 400,000 tons compared with rather less than 300,000 tons at the end of 1951. The survey mentions that about 10,000 tons of tram rails have been cleared in London and delivered to the steel works. It is expected that a further 30,000 to 40,000 tons will become available from that source during the present year.

Notes and Memoranda

Air and Water

ATLANTIC CROSSING OF THE "VISCOUNT."—On February 13th, the Vickers "Viscount 700" flew to Montreal for technical trials to ensure that it fully complies with the operational requirements of Trans-Canada Air Lines under extreme winter conditions. T.C.A. has ordered fifteen "Viscounts," the delivery of which will be completed by April, 1955. As the "Viscount" is not designed for trans-oceanic routes it was routed via Iceland and Greenland.

AUTOMATIC PILOT FOR JET AIRCRAFT.—It has been disclosed that the Sperry Gyroscope Company, Ltd., has developed a new precision aircraft automatic pilot scheduled for new aircraft for both naval aviation and the R.A.F. This equipment, which is now being put into production, includes a number of original design characteristics which enable this automatic pilot to meet the stability problems of high-speed aircraft. A considerable reduction in installed weight is effected, compared with other contemporary designs.

STEEL FOR SHIPBUILDING.—The First Lord of the Admiralty, Mr. J. P. L. Thomas, has stated in a written reply, that the steel allocation for shipbuilding in the second quarter of 1953 will be about 6 per cent higher than in the present quarter. The First Lord says that this is about the same rate of increase as has been made progressively each quarter since July 1, 1952. The reply adds that the steel requirements for ship repairs have always been a first charge on the total allocation and have been made in full in order to reduce to a minimum the period during which ships must be immobilised.

LECTURES ON WATER UTILISATION.—A course of four public lectures on the control of water for food production is being given at King's College, University of London, by Dr. Herbert Addison. The first lecture, which was held yesterday, was concerned with the general question of increased food production for an increasing world population, the effect of this problem on water resources, and the various forms of water control. The other lectures will be given at 5.30 p.m. on February 26th, March 3rd and 12th. Land reclamation in Europe and irrigation in the East will form the subjects of the next two lectures, and the last lecture will be concerned with combined water-power and irrigation projects and their problems and possibilities.

Miscellanea

MINE MECHANISATION.—The National Coal Board has produced two new instructional films dealing with mine mechanisation schemes. One of these films deals with automatic methods of unloading at the pit top at Kingshill Colliery in Scotland, and the other with the reconstructed pit bottom at Shilbottle Colliery, Northampton, where automatic tub-loading has been installed.

RUTHERFORD MEMORIAL LECTURE.—The council of the Royal Society has appointed as the Rutherford lecturer for 1953 Sir James Chadwick, F.R.S., who will deliver the lecture at McGill University, Montreal, in the Autumn. This is the second Rutherford lecture to be delivered under the terms of the Rutherford Memorial Fund, the first having been delivered last year in New Zealand by Sir John Cockcroft, F.R.S.

EXTENSION OF THE LUSSA HYDRO-ELECTRIC SCHEME.—The North of Scotland Hydro-Electric Board recently decided to extend its Glen Lussa project in Argyll, and the Secretary of State for Scotland has now confirmed this scheme. The annual output of the generating station in Glen Lussa will thus be increased from 8,500,000 units to 10,750,000 units, at an estimated cost of £310,000. Water will be diverted by tunnel from the upper tributaries of the River Barr into the reservoir of the existing scheme.

METAL AND PLASTIC SLIDES.—The Production Engineering Research Association of Great Britain has issued a new publication entitled "Developments in the Study of Metal and Plastic Slides." The publication outlines some problems associated with sliding surfaces and indicates the lines along which these problems are being investigated by the Association. Tests carried out on a wide range of materials and lubricants are described briefly, and a bibliography of articles dealing with various aspects of the problem is given at the end of the publication.

"LIVE LOADS ON FLOORS IN BUILDINGS."—The National Bureau of Standards, Washington 25, D.C., has published a report with the above title which presents information on the floor loads in various structures, such as office buildings, stores, factories, and warehouses. It gives details concerning a recent survey in which the weight and distribution of goods, equipment and occupants were obtained floor by floor and area by area. A method of reducing the assumed value for live load on structural members supporting large floor areas is also described.

OBITUARY.—We record with regret the death of Sir Geoffrey Savage, which occurred at his home near Stratford-on-Avon, on February 11th. Sir Geoffrey, who was sixty, was works director of the Rover Company, Ltd., Solihull, Birmingham, which company he joined in 1930. For the past three years he had been president of the Birmingham branch of the Engineering and Allied Employers' Association. . . . We have also learned with regret of the death, on February 11th, of Mr. Ernest B. Hall, chairman of the British Reinforced Concrete Engineering Company, Ltd., Stafford, and of the death, on February 12th, of Mr. S. R. Witt, A.M.I.E.E., superintendent of the transformer factory of the British Thomson-Houston Company, Ltd., Rugby.

BOILER SLACK.—The Fuel Efficiency Bulletin No. 53 recently published by the Ministry of Fuel and Power, is entitled "The Wetting of Slack to Assist Combustion." The report points out that it has long been known that the addition of water to boiler slack improves combustion, and in it an attempt has been made to explain the effects and assess the limitations and economies of slack conditioning. It also deals with the practical methods and safeguards which should be employed in slack conditioning. Copies of the bulletin can be obtained from Her Majesty's Stationery Office at 6d. net.

ALUMINIUM PASTE.—The British Aluminium Company, Ltd., has recently published a brochure, entitled "B.A. Aluminium Paste," which gives notes upon the general characteristics of aluminium paint and briefly discusses general purpose and special aluminium paints. A section deals with painting technique and describes surface preparation, embodies a table giving recommended paint systems, and also mentions the mixing and application of the paint. The booklet, which gives general information concerning the properties, storage and testing of paste, includes illustrations of marine, structural and industrial applications.

SIMPLE SLIDE RULE FOR MILLING MACHINE OPERATORS.—In order to assist setters, operators and ratefixers concerned with milling, a useful slide rule is now being issued by Clarkson (Engineers), Ltd., of Nuneaton. This slide rule gives speeds and feeds for keyseating and end milling operations with cutters from $\frac{1}{16}$in to 6in in the firm's "Autolock" and "Dedlock" range of tools. It is very simple to use and covers the machining of tough, medium and mild steels, cast iron, brass, phosphor bronze and aluminium. We are informed that these slide rules are only being issued to people on the shop floor—foremen, operators, setters and ratefixers—on personal application.

INSTITUTION OF METALLURGISTS.—The next examinations for the licentiateship and associateship of the Institution of Metallurgists will be held from August 24th to September 1st. Applications for permission to enter the examinations must be made, before May 1st, on forms which can be obtained from the Registrar of the Institution of Metallurgists, 4, Grosvenor Gardens, London, S.W.1. Examinations for the Fellowship of the Institution will also be held between August 24th and September 1st. Candidates intending to enter are asked to submit, for the approval of the Council, a statement of the dissertation or the branch of metallurgy in which they offer themselves for examination.

TEMPERATURE INDICATING PAINTS AND CRAYONS.—We are informed by Allied Colloids (Bradford), Ltd., 11, Great St. Thomas Apostle, Queen Street, London, E.C.4, that it is now supplying "Thermo-colour" temperature indicating powders and "Thermo-chrom" temperature indicating crayons. The powders are applied in the form of a paint after they have been mixed with industrial methylated spirits. These paints are designed to give an accurate indication of thermal zones and are useful for non-destructive material testing. The crayons, which work on a similar principle, are supplied in handy boxes containing twelve or fifteen sticks, and they can be carried around to provide quick and simple temperature testing means in a factory or other plant.

NATIONAL DIPLOMA IN AGRICULTURAL ENGINEERING.—The Institution of British Agricultural Engineers states that its *Farm Mechanisation* scholarship will again be awarded this year for the session of study commencing October, 1953. The award will be applied for the benefit of students who experience financial difficulty in completing the year of study leading to the final examination for the National Diploma in Agricultural Engineering and will be tenable at one of the Colleges approved by the examination board of the Institution. Preference will be given to candidates with engineering qualifications. Full particulars of the scholarship, together with forms of application, may be obtained from the Institution of British Agricultural Engineers, 24, Portland Place, London, W.1. The closing date for receiving completed applications is May 15, 1953.

THE ROBERT W. HUNT AWARD.—The board of the American Institute of Mining and Metallurgical Engineers announced recently that the Robert W. Hunt Award for 1953 would be given to Dr. J. H. Chesters, for his paper entitled "Flow Patterns in Open-Hearth Furnaces," presented at the 1951 conference at Cleveland, Ohio, and subsequently published in the *Open-Hearth Proceedings*. The Hunt Award was established in 1920 to commemorate a distinguished American metallurgist. Recipients are nominated by a continuing committee of four members of the iron and steel division, together with the chairman. The award is made for the best original paper or papers on iron and steel contributed to the Institute during the period under review. Dr. Chesters is assistant director of research at the United Steel Companies, Ltd., Sheffield.

"THE ROPEMAN'S HANDBOOK."—The National Coal Board has published a comprehensive manual of instruction on colliery wire ropes, written primarily for the assistance of ropemen in carrying out their duties in connection with the examination and care of winding, haulage, guide and balance ropes. Much of the material contained in the manual has been contributed by the Safety in Mines Research Establishment of the Ministry of Fuel and Power, and represents the results and conclusions of many years' study on the causes of breakage and serious deterioration of colliery wire ropes. The manual describes the construction, installation and the maintenance of the various ropes used for colliery work and the common causes of trouble experienced. Winding, haulage, guide and balance ropes are treated in separate chapters, each of which gives information about the choice of ropes and their installation, examination, care and lubrication. Other points covered are the various forms of capping for winding and haulage ropes; splicing; storage of ropes; and the circumstances under which a rope should be removed from service. The cost of the manual to the general public is 5s., but by special arrangement with the National Coal Board copies of it can be made available to officials and workmen of licensed coal mines, other mines under the Coal Mines Act, 1911, metalliferous mines, and quarries, at a reduced price of 3s. 3d., plus 3d. postage, if application is made to the National Coal Board, Production Department, Hobart House, Grosvenor Place, London, S.W.1.

ALUMINIUM WELDING.—The A.P.V. Company, Ltd., of Wandsworth Park, London, S.W.18, has sent us some notes on the manufacture of a 50,000 cubic foot transport tank for liquid oxygen, which is stated to be the first aluminium tank to be fabricated in this country using the "Aircomatic" welding process, in which the weld pool is protected from oxidation by an annular shield of argon gas. Unlike the earlier argonarc process, which uses a non-consuming tungsten electrode, in this "Aircomatic" process the arc is struck between the work and an aluminium wire which is fed forwards at high speed, the wire and weld pool being protected by argon gas from oxidation. The company states that the new process is particularly quick, and in the tank in question the circumferential fillets were welded continuously at a rate of 2ft a minute. We understand that the British Oxygen Company, Ltd., is to introduce equipment made in this country under the "Aircomatic" patents and to be known as the "Argonaut" process.

ELECTRONICS IN ATOMIC ENERGY.—The Atomic Energy Research Establishment, Harwell, is arranging a specialised course on the design, use and maintenance of electronic instruments used in nuclear physics, radiochemistry and in work with radio-isotopes. The course is to be held at the Isotope School, Harwell, from Monday to Friday, March 16th to 20th. It is limited to twelve people, and will include lectures and practical work on counters, d.c. and pulse amplifiers, coincidence units, scalers and ratemeters. The lecturers and demonstrators will be specialists from the Atomic Energy Research Establishment. The course is limited to physicists and electronic engineers holding a degree or equivalent qualification. The fee for the course is £12 12s., and living accommodation (at Buckland House near Faringdon, one of the A.E.R.E. senior staff hostels), transport and morning and evening meals will be provided at a charge of £7 7s. Application forms may be obtained from the Electronics Division, Atomic Energy Research Establishment, Harwell, near Didcot, Berks.

Personal and Business

MR. JAMES YOUNG, 53, Ardenlee Avenue, Belfast, has been appointed representative in Ireland of Peter Stubs, Ltd., Warrington.

VACUUM OIL COMPANY, Ltd., announces the appointment of Mr. R. C. Harrower as assistant manager of the Birkenhead works.

C. R. AVERILL, Ltd., Caergwle, Wrexham, announces the appointment of Mr. C. R. Averill, jun., as resident director in Scotland.

HIGGS MOTORS, Ltd., Witton, Birmingham, has appointed Mr. C. Williams as its technical sales engineer in the Liverpool district.

MR. J. C. MILNE, M.I.E.E., has been appointed assistant general manager of the Electric Construction Company, Ltd., Wolverhampton.

TUBELA ENGINEERING COMPANY, Ltd., 6, Furze Street, London, E.3, states that it is now distributing its products through normal trade channels instead of, as formerly, through a sole distributor.

BROOKS AND WALKER, Ltd., states that its Liverpool branch will be moved on April 1st to Brassiness House, Dale Street, Liverpool, 2 (telephone, Central 8341; telegrams, "Brassiness, Liverpool, 2").

CATTON AND CO., Ltd., 29, Chadwick Street, Leeds, 10, announces the appointment of Mr. Stanley Gittins, 22, Waterloo Road, Wolverhampton, as representative in Derbyshire, Staffordshire, Shropshire, Warwickshire, Worcestershire, and Oxfordshire.

METROPOLITAN-VICKERS ELECTRICAL COMPANY, Ltd., Trafford Park, Manchester, announces the appointment of Mr. C. H. Flurscheim, M.I.E.E., as assistant chief electrical engineer. He will continue his present duties as chief engineer in the switchgear department.

MR. G. A. BURRIDGE, secretary and director of Burton, Griffiths and Co., Ltd., has been appointed to the board of B.S.A. Tools, Ltd. Mr. F. A. Janes has been appointed to the board of Burton, Griffiths and Co., Ltd., and Mr. J. L. Parker has been appointed works manager of B.S.A. Tools, Ltd.

THE BUTTERLEY COMPANY, Ltd., announces the following appointments in its recently formed oxygen generator division:—Mr. H. W. Barnett, manager; Mr. A. A. C. Robertson, A.M.I.Mech.E., chief engineer; Dr. G. G. Haselden, consultant; Mr. H. P. Williams, purchasing agent. The headquarters of the division are at 20, Ashley Place, London, S.W.1 (telephone, Victoria 8023).

SIR GEORGE CHRISTOPHER has been appointed chairman and managing director of the Union-Castle Mail Steamship Company, Ltd., in succession to the late Sir Vernon Thomson, Bart. Sir Campbell Stuart has been appointed deputy chairman, Mr. J. S. Bevan has been appointed an assistant managing director, and Mr. R. J. Bloxam, who will continue to be the secretary of the company, has been appointed an assistant manager.

British Patent Specifications

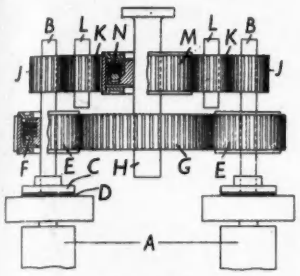
When an invention is communicated from abroad the name and address of the communicator are printed in italics. When an abridgment is not illustrated the specification is without drawings. The date first given is the date of application; the second date, at the end of the abridgment, is the date of publication of the complete specification.

Copies of specifications may be obtained at the Patent Office Sales Branch, 15, Southampton Buildings, Chancery Lane, W.C.2, 2s. 8d. each.

MARINE ENGINEERING

686,634. January 3, 1951.—SYNCHRONISING ENGINES FOR SHIP PROPULSION, Franz Süberkrüb, Chilehaus C/VII, Hamburg 1, Germany.

As the drawing shows, the engines *A* are permanently connected to the driving shafts *B* of the gearing by coupling means which may be disengaged only when the engines are stopped. The connecting ends are shown at *C* and *D*. The set of gear wheels for the ahead motion comprises pinions *E*, each of which

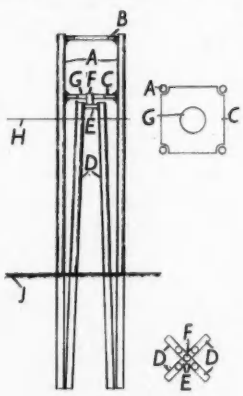


No. 686,634

is fitted with a clutch coupling *F* and is loosely mounted on one of the engine shafts *B*. The pinions *E* both mesh with a gear wheel *G* fixed on the propeller shaft *H*. For astern motion, pinions *J* are rigidly fixed on extensions of the shafts *B* and through interposed reversing pinions *K* fixed on auxiliary shafts *L*, indirectly mesh with a gear wheel *M* mounted on the propeller shaft *H*, to which the wheel may be connected by a clutch *N*. In order to obtain ahead motion of the propeller, the clutch *N* is disengaged while the clutches *F* are engaged. For astern motion the clutches *F* are disengaged and the clutch *N* is engaged. During all manœuvres the engines continue to turn and in the same direction. The synchronised running of the engines is maintained because the pinions *J* are fixed to the engine shafts and, due to their meshing with the wheels *K* and *M*, there is a closed gear train between the two shafts. In addition, it is necessary that the extensions of the engine shafts *B* and the engine crankshafts shall be permanently connected to each other by the clutches *C* and *D* in such a way that the corresponding cranks have the same position and the sequence of ignition is timed uniformly. A modified design is also shown in the specification.—*January* 28, 1953.

686,507. May 4, 1951.—MULTI-SECTION DOLPHINS FOR SHIPS, Westdeutsche Mannesmannrohren Aktiengesellschaft, 125, Ulmenstrasse, Dusseldorf, Germany.

The drawing shows an eight-pile dolphin in which the ring of the outer piles *A* is united to form the dolphin section by connections *B* and *C*, which are not thrust-resisting. The ring of the inner four piles *D* is joined to form the rigid or substantially rigid dolphin section by a thrust-resisting connection *E*, which is connected to the piles *D* at the upper ends.



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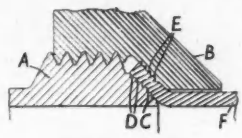
The connection *E* carries a pin *F* which freely engages in a recess *G* in the lower connection *C* of the outer ring. The lower plan view shows the inner ring with its connection *E*. The line *H* represents the level of the water and the line *J* the sea or river bed into which the piles are driven. In the specification, alternative types of multiple piles with yieldable and rigid connections are shown and described.—*January* 28, 1953.

TUBE AND PIPE COUPLINGS

686,275. November 3, 1950.—PIPE COUPLINGS, Frank Kay, The Elms, Clifton Drive, Lytham, Lancashire.

Referring to the drawing, it will be seen that the pipe to be connected has a thimble *A*, which is screwed for a union nut *B* and has at the inner end a coned face *C* with serrations *D* forming a number of ring-like teeth. The union nut *B* has similar teeth *E* formed on its inner surface and the flared end of the



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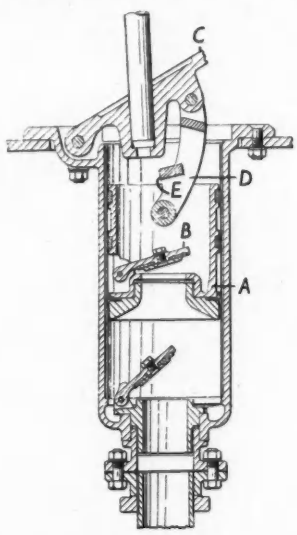
pipe *F* is jointed firmly between the two serrated faces. An alternative design in which ring members carry the serrated faces is also shown in the specification. The main object of the invention is to minimise the risk of the serrations engaging only the edge of the flared tube or near the root. The design is such that the inner surface of the flare first meets the teeth at the centre, where the most useful grip is obtained.—*January* 21, 1953.

PUMPS

686,623. October 30, 1950.—LIFT PUMPS, Munster, Simms and Co., Ltd., Imperial House, Donegall Square East, Belfast, Northern Ireland. (*Inventors: Frederick Sydney Eves and Herbert Montague Harris.*)

The cylinder of a deck-discharge bilge pump shown in the drawing, has the usual hinged inlet valve at its bottom end and is flanged at its upper end for clamping to the deck. The bucket *A* with the usual hinged valve *B* at its base reciprocates in the cylinder and discharges through the open upper end of the cylinder on to the deck. A lid *C* for closing the upper end of the cylinder when the pump is out of use is hinged at the top. The hinge is housed in a recess in the cylinder flange. The end of the lid



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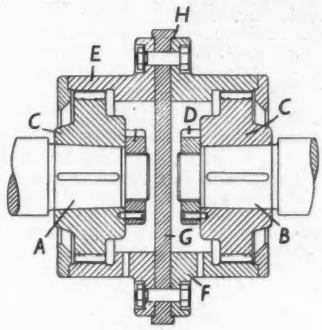
opposite the hinge is connected to the bucket by a duplex link *D*. An operating handle projecting upwards from the top of the lid is used with the lid and duplex link to form a lever system for actuating the pump. A cross-bar *E*, extending between the arms of the duplex link, engages the boss on the lid to limit upstroke movement, whilst the lid engages its seating at the upper end of the cylinder to limit downstroke movement. The weight of the bucket is such that it automatically closes the lid and a detachable pin on the lid enables ready removal of the bucket to clear the bottom inlet valve if it becomes choked.—*January* 28, 1953.

TURBINES AND TURBO-COMPRESSORS

685,811. January 26, 1951.—SHAFT COUPLINGS FOR HIGH SPEEDS, Escher Wyss Aktiengesellschaft, Escher Wyss Platz, Zürich, Switzerland.

As shown in the drawing, *A* and *B* are the two slightly tapered ends of the two shafts to be connected. Keyed to each is a male coupling member *C* with external teeth and secured to the shafts by nuts *D*. An internally-toothed member connecting the two male members is made in two halves *E*. The opposing ends of the members *E* are formed as flanges *F*, and a centring disc *G* between them has two shoulders *H*. The two halves and the centring disc are bolted together. During running the flanged ends of the



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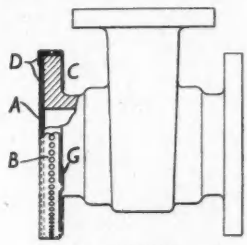
coupling members *E* bear against the annular shoulders of the centring disc, which is solid at the centre, and thus prevent any radial deformation due to the action of centrifugal forces. End covers are fitted as shown. The coupling has been designed for coupling together machinery with shafts which permit of little, if any, axial displacement.—*January* 14, 1953.

VALVES

685,908. September 7, 1951.—MEANS FOR PROTECTING A FLANGE, G. Dikkers and Co., N.V., 15, Industriestraat, Hengelo, The Netherlands. (*Inventor: Jacob Das.*)

The invention relates to means for protecting a flange against damage of the machined face during transport in unpacked condition. As the drawing



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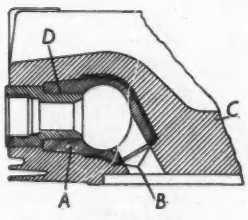
clearly shows, the flange of a valve is covered by a sheet of hard board or other material *A*, which closes the bore. The sheet is held in position by a strip of hoop iron *B* which, on the inner side, has tongues *C*, and on the outside triangular teeth *D*. The strip has perforations around it, and the ends of the strip are lapped over each other and secured by a pin. The outer teeth are beaten down on to the face of the disc, and the inner tongues have holes for wire lacing. Such strips can conveniently be used for various thicknesses of flanges and protecting discs.—*January* 14, 1953.

INTERNAL COMBUSTION ENGINES

685,809. January 24, 1951.—COMBUSTION CHAMBERS OF INTERNAL COMBUSTION ENGINES, Porsche Konstructionen G.m.b.H., 5, Alpenstrasse, Salzburg-Morzg, Austria, formerly of Gmünd, Carinthia, Austria.

Referring to the drawing, it will be seen that the combustion chamber is heat insulated from the cylinder head, with the object of reducing the temperature drop. The finished hollow combustion head *A* is



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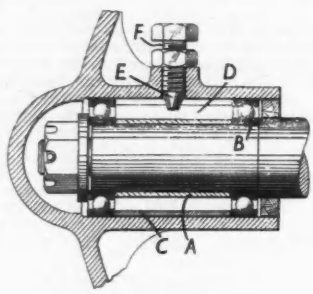
coated with a layer of heat-insulating material *B* before it is cast into the cylinder head *C*. The material used may be graphite or ceramic powder, combined with a binding agent to make a paste.

Care is taken not to apply paste to the region *D*, forming the seating of the nozzle which must always be kept relatively cool. The insulating paste having dried, the combustion chamber is inserted into the mould and cast into the cylinder head. The solid, heat-resisting layer thus formed, screens the combustion head from the cylinder head and there is no noticeable drop of temperature in the combustion chamber, which heats up rapidly when starting, and remains hot. An alternative construction with ribs cast on the portion of the combustion head forming the nozzle seating, to promote heat transmission in special cases, is also shown in the specification.—*January* 14, 1953.

POWER TRANSMISSION

686,652. July 31, 1951.—SECURING OF A HUB TO A SPINDLE, Ateliers de Constructions Mecaniques de Vevey S.A., Vevey, Switzerland. (*Inventor : Maurice Bonjour.*)

As the drawing indicates, two ball bearings are placed on the machined end of the shaft, the distance between them being determined by a tube *A*. A nut screwed on to the end of the axle, forces, by a washer, the bearing against the tube *A*, which in turn presses it against the shoulder *B*, the two ball bearings thus



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being secured rigidly to the shaft. A sleeve *C* having a slit *D* parallel to its axis, is fitted into the hub bore, between the bearings. The middle of the slot has a hole *E* which receives the conical end of a screw *F*. By the invention, it is claimed that the securing of the hub on the ball bearings is very easy. It suffices to slide the hub axially on the ball bearings between which the split sleeve *C* has been placed in such a manner that the screwed bore *E* is opposite the hole *F*. Tightening of the screw enlarges the slit of the sleeve to increase its diameter, until it applies a strong pressure against the inner wall of the hub. A modification is also shown in the specification.—*January* 28, 1953.

Books of Reference

Newnes Engineers Reference Book. Fifth edition. Edited by F. J. Camm. London : George Newnes, Ltd., Tower House, Southampton Street, W.C.2. Price 63s.—The vast amount of useful, up-to-date information and data given in this book for engineers in all branches of industry has been extended, revised and rearranged. Some three hundred new tables are stated to have been added, together with new chapters on mechanics and mechanisms, broaching, single-spindle automatics, &c. The clear subdivision of the sections combined with an excellent index enables the user to trace quickly and easily the information he requires. As in former editions, the subject matter is well supplemented by numerous diagrams and drawings.

The Electrical Trades Directory : The Electrical Journal "Blue Book," 1953. Edited by S. G. Rattee, A.M.I.E.E., and E. J. Harper. London : Benn Brothers, Ltd., 154, Fleet Street, E.C.4. Price 50s.—The new edition of this well-known reference book once again provides in a convenient form comprehensive details of the products of the British electrical and allied trades, and a mass of other information relating to the electrical industry. It is arranged on the same general lines as in the previous edition, but, in addition to information having been revised and brought up to date, some 500 new names are to be found in the list of manufacturers, and the trade names section has been extended. A short section has been introduced giving interesting facts and figures about electricity supply, the manufacturing industry, &c. To assist new users who are not familiar with the book a brief explanation is now given of the simple method by which any required details may be found. Projecting guide tabs have also been introduced at the beginning of each main section of the book to facilitate reference.

Launches and Trial Trips

LONDON SPLENDOUR, oil tanker ; built by the Furness Shipbuilding Company, Ltd., for London and Overseas Freighters, Ltd.; length between perpendiculars 560ft, breadth moulded 80ft, depth moulded 42ft 3in, deadweight 24,600 tons on 32ft 3½in summer draught ; corrugated bulkheads, twenty-seven cargo oil tanks, two pump rooms, four Duplex 500 tons per hour steam pumps, two stripping pumps, Butterworth tank cleaning system, two 75kW steam-driven generators, one 35kW diesel-driven generator ; Wallsend-Doxford single-acting, two-stroke, oil engine, six cylinders 670mm diameter by 2320mm combined stroke, 6600 b.h.p. at 116 r.p.m., two Scotch boilers. Trial January 27th.

HARPA, oil tanker ; built by Harland and Wolff, Ltd., for the Anglo Saxon Petroleum Company, Ltd.; length between perpendiculars 530ft, breadth moulded 69ft 3in, depth moulded 39ft, deadweight 18,000 tons ; a single set of double reduction geared turbines, 7500 s.h.p., steam supplied at 500 lb per square inch and 800 deg. Fah. by two Babcock and Wilcox water-tube boilers, two 550kW turbo-alternators and one 200kW diesel-driven alternator. Launch January 29th.

MERCHANT BARON, oil tanker ; built by the Furness Shipbuilding Company, Ltd., for the Drake Shipping Company, Ltd.; length between perpendiculars 525ft, breadth moulded 71ft, depth moulded 39ft 3in, deadweight 18,025 tons, draught 30ft 5½in ; N.E.M.-Doxford single-acting two-stroke oil engine, six cylinders 670mm diameter by 2320mm combined stroke, 6800 b.h.p. at 119 r.p.m., two Scotch boilers. Launch January 29th.

JANOVA, oil tanker ; built by Harland and Wolff, Ltd., for Anders Jahre and Coy., Norway ; length between perpendiculars 540ft, breadth moulded 73ft, depth moulded 39ft 3in, deadweight 18,500 tons, twenty-seven cargo oil tanks, two main pump rooms ; Harland-B. and W. single-acting, two-cycle, opposed-piston oil engine, six cylinders, 750mm diameter by 2000mm combined stroke, 114 r.p.m., two single-ended multitubular boilers, one 75kW diesel-driven generator and two 75kW steam-driven generators. Trial January 30th.

HEMBO, diesel tug ; built by Philip and Son, Ltd., for the Union Lighterage Company, Ltd.; length between perpendiculars 75ft, beam 20ft, depth 10ft 6in, speed 10 knots, pull 5·7 tons : Ruston and Hornsby diesel engine, 560 b.h.p. at 430 r.p.m. Trial January 30th.

VIGILANT, steam tender ; built by John I. Thornycroft and Co., Ltd., for the Mersey Docks and Harbour Board ; length 172ft, breadth 35ft, speed 12·5 knots, machinery 1450 i.h.p., 440 tons per hour fire and salvage pump. Launch February 3rd.

Forthcoming Engagements

Secretaries of Institutions, Societies, &c., desirous of having notices of meetings inserted in this column, are requested to note that, in order to make sure of their insertion, the necessary information should reach this office on, or before, the morning of the Monday of the week preceding the meetings. In all cases the TIME *and* PLACE *at which the meeting is to be held should be clearly stated.*

CHEMICAL SOCIETY

Thurs., Feb. 26th.—Lecture Theatre, Royal Institution, Albemarle Street, London, W.1, "Some Applications of the Separation of Large Molecules and Colloidal Particles," A. Tiselius, 7.30 p.m.

HULL CHEMICAL AND ENGINEERING SOCIETY

Tues., Feb. 24th.—Church Institute, Albion Street, Hull, "Some Chemical Aspects of Motor-Car Manufacture," H. J. Mason, 7.30 p.m.

ILLUMINATING ENGINEERING SOCIETY

Tues., Feb. 24th.—CARDIFF CENTRE : S. Wales Electricity Board, Cardiff, "Modern Airport Lighting," J. W. Morse, 5.45 p.m. ——LIVERPOOL CENTRE : Merseyside and N. Wales Electricity Board's Service Centre, Whitechapel, Liverpool, "The Development of the Tungsten Lamp," B. P. Dudding, 6 p.m.
Wed., Feb. 25th.—INFORMAL MEETING : Lighting Service Bureau, 2, Savoy Hill, London, W.C.2, Discussion on the Lighting of Pedestrian Crossings, 6 p.m.——SWANSEA GROUP : Minor Hall, Y.M.C.A., Swansea, "Modern Airport Lighting," J. W. Morse, 6 p.m.
Thurs., Feb. 26th.—BRADFORD GROUP : Yorkshire Electricity Board, 45–53, Sunbridge Road, Bradford, "Interior Decoration and its Influence on Lighting," 7.30 p.m.

INCORPORATED PLANT ENGINEERS

Mon., Feb. 23rd.—W. AND E. YORKS BRANCH : The University, Leeds, "Visit to America as a Member of the Fuel Conservation Team," W. A. Wordley, 7.30 p.m.
Thurs., Feb. 26th.—S. YORKSHIRE BRANCH : Grand Hotel, Sheffield, Short Papers by Members, 7.30 p.m.
Fri., Feb. 27th.—BIRMINGHAM BRANCH : Imperial Hotel, Temple Street, Birmingham, "The Development of Mechanical Excavators," L. V. Nelson ; "Modern Crawler Tractors," G. H. Shaw, 7.30 p.m.

INSTITUTE OF BRITISH FOUNDRYMEN

Wed., Feb. 25th.—Waldorf Hotel, London, W.C.2, "Experiences with Hot Blast Cupolas in Great Britain," F. C. Evans, 7.30 p.m.

INSTITUTE OF FUEL

Tues., Feb. 24th.—Institution of Mechanical Engineers, Storey's Gate, St. James's Park, London, S.W.1, "The International Flame Radiation Trials at Ijmuiden, Holland," introductory remarks by O. A. Saunders, followed by a summary of the technical aspects of the trials, presented by M. W. Thring, 5.30 p.m.

INSTITUTE OF NAVIGATION

To-day, Feb. 20th—Royal Geographical Society, 1, Kensington Gore, London, S.W.7, "Navigation and the Operation of Jet Aircraft," R. C. Alabaster, 5 p.m.

INSTITUTION OF BRITISH AGRICULTURAL ENGINEERS

Tues., Feb. 24th.—Institution of Electrical Engineers, Savoy Place, London, W.C.2, "Recent and Present Work at the N.I.A.E.," W. H. Cashmore, 2.15 p.m.

INSTITUTION OF CIVIL ENGINEERS

Tues., Feb. 24th.—WORKS MEETING : Great George Street, Westminster, London, S.W.1, "The Application of Precast Concrete to the Construction of Acton Power Station," A. G. S. Lance and J. A. Derrington, 5.30 p.m.
Fri., Feb. 27th.—YORKSHIRE ASSOCIATION : Royal Station Hotel, York, "Claerwen Dam, Design and Construction of 200ft High Gravity Dam," P. Scott, 7 p.m.
Tues., Mar. 3rd.—AIRPORT MEETING : Great George Street, Westminster, London, S.W.1, "Methods of Soil Stabilisation and Their Application to the Construction of Airfield Pavements," D. J. Maclean and P. J. M. Robinson, 5.30 p.m.

INSTITUTION OF ELECTRICAL ENGINEERS

To-day, Feb. 20th.—EDUCATION DISCUSSION CIRCLE : Savoy Place, London, W.C.2, Discussion on "Circuit Conventions, with Particular Reference to Alternating-Current Circuit Vector Diagrams," opened by J. G. Fleming, 6 p.m.
Mon., Feb. 23rd.—RADIO SECTION : Savoy Place, London, W.C.2, "Radio Aids for Airport Control," G. W. Stallibrass, 5.30 p.m.
Wed., Feb. 25th.—SUPPLY SECTION : Savoy Place, London, W.C.2, "The Testing and Specification of Bushings in Relation to Service Conditions," H. Barker and H. Davies, 5.30 p.m.
Thurs., Feb. 26th.—Grosvenor House, Park Lane, London, W.1, Annual Dinner, 7 p.m.
Monday, Mar. 2nd.—S. MIDLAND CENTRE : James Watt Memorial Institute, Great Charles Street, Birmingham, "Review of Electricity Applied to Mining," B. L. Metcalf, 6 p.m.
Tues., Mar. 3rd.—MEASUREMENTS AND RADIO SECTION : Savoy Place, London, W.C.2, "The Study of a Magnetic Inverter for Amplification of Low-Input-Power D.C. Signals," E. H. Frost-Smith ; "The Parallel-T.D.C. Amplifier : A Low-Drift Amplifier with Wide Frequency Response," P. S. T. Buckerfield, 5.30 p.m.——S.W. SCOTLAND SUB-CENTRE : Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, C.2, "The Place of Steam, Water and Wind Power in an Integrated Scheme for the Generation of Electricity," C. W. Marshall, A. Feiner and J. Venters, 7 p.m.

INSTITUTION OF ENGINEERING INSPECTION

Thurs., Feb. 26th.—N.W. BRANCH : Engineers' Club, Albert Square, Manchester, "Metallurgical Topics in the Manchester Memoirs," H. J. Axon, 7.30 p.m.

INSTITUTION OF ENGINEERS AND SHIPBUILDERS IN SCOTLAND

Tues., Feb. 24th.—39, Elmbank Crescent, Glasgow, C.2, "Inspection Problems in the Manufacture of Modern Jet Engines," C. Garside, 6.30 p.m.
Fri., Feb. 27th.—Robert Gordon's Technical College, Aberdeen, "Textile Finishing Machines," K. S. Laurie, 7.45 p.m.

INSTITUTION OF MECHANICAL ENGINEERS

To-day, Feb. 20th.—GENERAL MEETING : Storey's Gate, St. James's Park, London, S.W.1, "An Investigation of Fretting Corrosion," K. H. R. Wright, 5.30 p.m.
Tues., Feb. 24th.—S. WALES BRANCH : Mackworth Hotel, Swansea, "Exhaust Arrangements and Their Influence on the Power Output of Internal Combustion Engines," T. J. Williams, 6 p.m.
Fri., Feb. 27th.—GENERAL MEETING arranged in conjunction with the INDUSTRIAL ADMINISTRATION AND ENGINEERING PRODUCTION GROUP : Storey's Gate, St. James's Park, London, S.W.1, "Developments in Steel Castings in the Heavy Power Plant Industry," F. Buckley, 5.30 p.m.——WESTERN BRANCH. GRADUATES' SECTION : Grand Hotel, Bristol, "Research Methods in the Commercial Gas Turbine Field," M. E. Ginniff, 7 p.m.

INSTITUTION OF STRUCTURAL ENGINEERS

Tues., Feb. 24th.—LANCASHIRE AND CHESHIRE BRANCH : Reynolds Hall, College of Technology, Manchester, "Developments in the Design of Sheet Pile Walls," P. W. Rowe, 6.30 p.m.
Thurs., Feb. 26th.—11, Upper Belgrave Street, London, S.W.1, "Soil Mechanics in Relation to Structural Engineering," P. L. Capper, 6 p.m.
Fri., Feb. 27th.—MIDLAND COUNTIES BRANCH : James Watt Memorial Institute, Great Charles Street, Birmingham, "Experiences with Concrete," N. T. Grant, 6 p.m.

JUNIOR INSTITUTION OF ENGINEERS

To-day, Feb. 20th.—INFORMAL MEETING : Townsend House, Greycoat Place, London, S.W.1, "Whole House Heating," H. S. Walter, 7 p.m.
Tues., Feb. 24th.—N.W. SECTION : Engineers' Club, Albert Square, Manchester, "The Air and the Future," F. R. Banks, 7.15 p.m.
Wed., Feb. 25th.—MIDLAND SECTION : Room A5, Technical College, Coventry, "Automatic Feed Pressworking," C. H. Crawford, 7 p.m.
Fri., Feb. 27th.—Townsend House, Greycoat Place, London, S.W.1, "Electronics in Materials Handling," L. Landon Goodman, 7 p.m.

MANCHESTER ASSOCIATION OF ENGINEERS

Fri., Feb. 27th.—Engineers' Club, Albert Square, Manchester, "The Testing of Motor Vehicles," G. H. Swindlehurst, 6.45 p.m.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS

Fri., Feb. 27th.—Mining Institute, Newcastle upon Tyne, "Wave Studies of Plane Surfaces," J. F. Allan and R. S. Cutland, 6.15 p.m.

ROYAL AERONAUTICAL SOCIETY

Tues., Feb. 24th.—GRADUATES' AND STUDENTS' LECTURE : 4, Hamilton Place, London, W.1, "Viscount Operations," R. Rymer, 7.30 p.m.
Thurs., Feb. 26th.—Institution of Mechanical Engineers, Storey's Gate, St. James's Park, London, S.W.1, "New Materials and Methods for Aircraft Structure," H. J. Pollard, 6 p.m.

ROYAL SOCIETY OF ARTS

Wed., Feb. 25th.—John Adam Street, Adelphi, London, W.C.2, Cadman Memorial Lecture, "Improving Coal Production," E. H. Browne, 2.30 p.m.

ROYAL STATISTICAL SOCIETY

Wed., Feb. 25th.—London School of Hygiene and Tropical Medicine, Keppel Street, London, W.C.1, "A Sampling Design Used by the Ministry of Education," G. F. Peaker, 5.15 p.m.

SOCIETY OF CHEMICAL INDUSTRY

Tues., Feb. 24th.—CHEMICAL ENGINEERING GROUP JOINT MEETING WITH PLASTICS GROUP : Burlington House, Piccadilly, London, W.1, "Synthetic Resin Cements Used in Chemical Engineering Practice," E. K. Earp, S. Shapiro and A. E. Wiggs ; "Corrosion-Resisting Properties of Some Synthetic Resin Cements," V. Evans.

SOCIETY OF INSTRUMENT TECHNOLOGY

Tues., Feb. 24th.—Manson House, Portland Place, London, W.1, "Geophysical Prospecting for Oil," D. T. Germain-Jones, 6.30 p.m.